MONTHLY WEATHER REVIEW

CHARLES F. BROOKS, Editor.

Vol. 47, No. 9.
W. B. No. 695.

SEPTEMBER, 1919.

Closed Nov. 4, 1919
Issued Dec. 16, 1919

RAINFALL INTERCEPTION.

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[Dated: Albany, N. Y., Sept. 3, 1919.]

Synopsis.—1. Rainfall interception represents a loss of precipitation which would otherwise be available to the soil.

2. The loss takes place through evaporative processes, but may, for convenience, be subdivided into (a) interception storage, and (b) evaporation during rain.

3. The amount of interception loss is primarily a function of the storage capacity of the plant surface, the duration of precipitation, and the evaporation rate during precipitation.

4. Since there is generally a fairly close correlation between shower duration and amount of precipitation, estimates of interception loss can, for practical purposes, be expressed in terms of precipitation amount per shower.

5. The interception storage loss for trees varies from 0.02 to 0.07 inch per shower, and approaches these values for well-developed crops.

6. The interception storage loss for trees in woods is greater, but the evaporation loss during rain is less than for trees in the open.

7. The percentage of total precipitation loss is greater in light than in heavy showers, ranging from nearly 100 per cent where the total rainfall does not exceed the interception storage capacity to about 25 per cent as an average constant rate for most trees in heavy rains of long duration.

8. Light showers are much more frequent than heavy ones, and the interception loss for a given precipitation in a month or season varies largely, according to the rainfall distribution.

9. Expressing the interception loss in terms of depth on the horizontal projected area shadowed by the vegetation, the loss per shower of a given amount is very nearly the same for various broad-leaved trees during the summer season.

10. The amount of water reaching the ground by running down the trunks of trees may amount to a relatively large volume when measured in gallons for a smooth bark tree in a long heavy rain. It is, however, a relatively small percentage, commonly 1 to 5 per cent, of the total precipitation. The percentage increases from zero in light showers to a maximum constant percentage in heavy showers of long duration.

11. Different interceptometers under the same tree will give fairly consistent results, if so placed that they do not receive direct rainfall, and if they stand under a complete leaf cover of average density.

12. So far as the experimental data go, there is little evidence of watershed effect or dripping of water from the periphery of the crown to a greater extent than through the crown itself.

13. The interception loss from needle-leaved trees, such as pines and hemlocks, is greater both as regards interception storage and evaporation during rain than from broad-leaved trees.

14. The average duration of showers of a given intensity is greatest in winter and the colder summer months, and least in midsummer or thunder-storm months, whereas the evaporation rate is greatest in midsummer and least in the colder months. As a result of the opposite effects of these two factors affecting interception loss, the average loss per shower of a given intensity seems to be nearly constant throughout the different months of the summer period, May to October, inclusive.

15. Data are insufficient for a final determination of the relative losses from trees in winter and in summer. Apparently the winter and summer losses for a given monthly precipitation for needle-leaved trees are about equal, whereas for deciduous, broad-leaved trees the winter interception loss appears to be about 50 per cent as great when the trees are defoliated as during the growing season.

16. Interception loss from full-grown field crops approaches in value that from trees, but owing to the short time during which crops stand on the ground in a fully developed stage of growth, the total annual interception loss from cropped areas is very much smaller than from wooded areas.

17. The average interception loss from 11 trees, excluding peripheral interceptometers and excluding hickory, for which the results are defective, during the summer of 1918 was 40 per cent of the precipitation.

INTRODUCTION.

A large amount of data has been accumulated on this subject. There does not appear, however, to have been any thorough and complete analysis of all the available data, and it is unfortunate that not even a reasonably complete digest of the experimental observations is available in English. Furthermore, the processes involved do not seem to have been carefully analyzed, and, as a result, many of the experimental data are not in a form permitting interpretation of the results to the best advantage.

The subject is one on which it is somewhat difficult to experiment in a satisfactory manner, and it is not surprising that the conclusions hitherto drawn by different authorities are sometimes at variance, and many of the data are seemingly discordant.

Table No. 1.—*Summary of rainfall interception data for forests.*

Wood.	Per cent loss.			Station, duration, authority, etc.
	Winter.	Summer.	Year.	
(1)	(2)	(3)	(4)	(5)
Mixed			25	16 German stations (ref. 1), p. 106,
Do			16	3 Swiss stations (ref. 1) 16-year average, p. 106.
(?)			16	Nancy, Bellefontaine, 11 years.
Evergreens	20.90	[1] 26	[2] 23	German stations (ref. 1), p. 107.
Deciduous	19.60	[1] 35	[2] 26	Do.
General average	21.40	[1] 30	[2] 25	
Larch			15	Swiss stations, 12 years (ref. 1), p. 131.
Spruce			23	
Beech			10	
Do			24	Prussian stations (ref. 1), p. 131.
Spruce			27.7	Do.
Do			39	Raphael Zon (ref. 10), p. 230.
Broad leaved			13	Raphael Zon.
Beech			15	Raphael Zon, from Ney: crown loss after deducting trunk run-off (ref. 10), p. 230.
Pine			20	
Spruce			33.33	
Blue beech	5.85		8.48	Mathieu at Nancy, 11 years (ref. 10, p. 231).
Beech, 20-year			2	Bühler, 2 to 3 years (ref. 10, p. 230).
Beech, 50-year			27	
Beech, 60-year			23	
Beech, 90-year			17	

a Forest influences.
b Final report National Waterways Commission.
[1] May–Sept. 5/12 year.
[2] Approximate, deduced by proportion from columns (2) and (3).

Table No. 1 contains a digest of the results of different experiments, and of the conclusions of different authorities therefrom.

In comparison with some of the European results, the following statement by H. S. Graves is pertinent: (Monthly Weather Review, Dec., 1914, **42**: 671).

Many and exact measurements have demonstrated that a forest cover intercepts from 15 to 80 per cent of the precipitation, according to the species of trees, density of the stand, age of the forest, and other factors. Thus pine forests of the North intercept only about 20 per cent, spruce about 40 per cent, and fir nearly 60 per cent of the total precipitation that falls in the open, the amount that runs off along the trunks in some species is very small, less than 1 per cent, in others, beech for instance, it is 5 per cent.

Harrington in Forest Influences, (1) says:

"It seems that the deciduous trees withhold more of the precipitation through the entire year than do the evergreens."

Zon (10) states:

"As a result of a great number of investigations it may be assumed that coniferous forests intercept more precipitation than broad-leaved forests."

Imbeaux gives the opinion that the interception loss is 50 per cent in coniferous, and 20 to 30 in deciduous woods. (Essai-Programme of Hydrology.)

PHYSICS OF RAINFALL INTERCEPTION.

It is a matter of common observation that the percentage of precipitation reaching the ground in forest or on fields with growing crops is very small in the earliest stages of a rain, increasing as the duration of the storm increases, the total amount reaching the ground being small for short light showers, and increasing for severe prolonged storms. General observations also lead to the following conclusions:

When rain begins, drops striking leaves are mostly retained, spreading over the leaf surfaces in a thin layer or collecting in drops or blotches at points, edges, or on ridges or in depressions of the leaf surface. Only a meager spattered fall reaches the ground, until the leaf surfaces have retained a certain volume of water, dependent on the position of the leaf surface, whether horizontal or inclined, on the form of the leaf, and on the surface tension relations between the water and the leaf surface, on the wind velocity, the intensity of the rainfall, and the size and impact of the falling drops. When the maximum surface storage capacity for a given leaf is reached, added water striking the leaf causes one after another of the drops to accumulate on the leaf edges at the lower points. Each drop grows in size (the air being still) until the weight of the drop overbalances the surface tension between the drop and the leaf film, when it falls, perhaps to the ground, perhaps to a lower leaf hitherto more sheltered. These drops may also be shaken off by wind or by impact of rain on the leaf. The leaf system temporarily stores the precipitation, transforming the original rain drops usually into larger drops. In the meantime the films and drops on the leaves are freely exposed to evaporation.

It is evident that the amount of interception in a given shower comprises two elements. The first may be called interception storage. If the shower continues, and its volume is sufficient, the leaves and branches will reach a state where no more water can be stored on their surfaces. Thereafter, if there is no wind, the rain would drop off as fast as it fell, were it not for the fact that even during rain there is a considerable evaporation loss from the enormous wet surface exposed by the tree and its foliage. As long as this evaporation loss continues and after the interception storage is filled, the amount of rain reaching the ground is measured by the difference between the rate of rainfall and the evaporation loss. When the rain ceases the interception storage still remains on the tree and is subsequently lost by evaporation. If there is wind accompanying the rain, then, owing to motion of the leaves and branches, it is probable that the maximum interception storage capacity for the given tree is materially reduced as compared with still air conditions. Furthermore, in such a case, after the rain has ceased, a part of the interception storage remaining on the tree may be shaken off by the wind, and the storage loss in such a case is measured only by the portion of the interception storage which is lost by evaporation and is not shaken off the tree after the rain has ceased. One effect of wind is, therefore, to reduce materially the interception storage. As regards evaporation loss during rain, the effect of wind is, of course, to increase it materially.

The difference between interception losses with and without wind is illustrated by the accompanying figure 1. If there is no wind, and the rain falls gently, it is nearly all intercepted until the interception storage capacity is reached—thereafter in the absence of wind, evaporation proceeds slowly, the remainder of the precipitation dripping off the leaves, generally in large drops, and reaching the ground. For a sharp shower with wind, the interception storage is filled only to a limited extent, drops being temporarily stored on the leaves and then shaken off. The evaporation rate may, however, be materially increased, so that while the depth of interception during the earlier part of the storm is likely to be less than for a storm without wind, the total interception depth for a

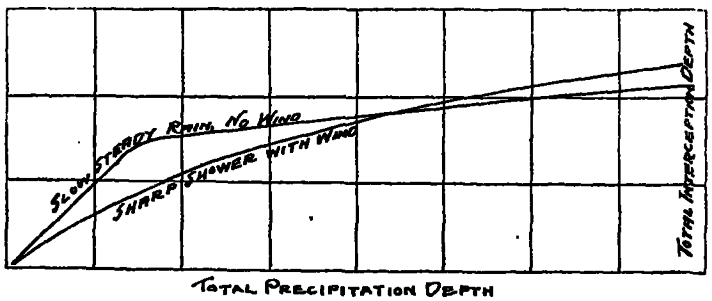

FIG. 1.—The effect of wind and character of shower on interception loss.

long-continued storm with wind may be the greater of the two, owing to increased evaporation.

The maximum interception storage can be approximately determined from records taken for short, light showers, during which nearly all the rainfall was intercepted.

The fundamental storage equation—inflow equals outflow plus gain, or, minus loss of storage—applies to this process, but after the leaf storage is saturated, leaves are freely exposed to evaporation, the inflow rate minus evaporation rate equals outflow rate.

For the storm as a whole, the following relation holds:

Inflow minus total evaporation during storm equals total outflow plus leaf storage at end of storm.

It will be seen that during the greater portion of a long rain capable of producing a severe storm, run-off rate equals precipitation rate minus evaporation rate. In general, for a storm sufficient to saturate the leaf storage.

Total interception equals leaf storage capacity plus evaporation loss during the storm.

Owing to the great extent of leaf surface, the evaporation loss from leaf surfaces is much greater than from the projected area shaded by the tree, but is likely to be relatively small per unit of exposed surface compared with the evaporation rate in fair weather, owing to the smaller saturation deficit common during rain, and the approximate equality between leaf-surface and air temperature.

The superficial storage capacity of a plant is approximately constant at a given stage of growth or leaf development. By storage capacity is meant the depth of water on the projected area covered by the plant which can be stored or detained on the plant surface in still air.

If T = duration of the storm in hours.

E_r = evaporation rate in inches depth per hour during the storm.

K_1 = ratio of the evaporation surface to the projected area.

S_j = interception storage capacity in inches depth on the projected area.

P = precipitation rate per unit of time.

Then the total interception loss is—

$$J = S_j + K_1\ E_r\ T \qquad (1)$$

and the percentage loss—

$$\frac{J}{PT} = \frac{S_j + K_1\ E_r\ T}{PT} \qquad (2)$$

This formula indicates that the percentage loss decreases as the duration of the storm increases; and furthermore, since the numerator is independent of the rain intensity, the percentage loss decreases as the intensity of the storm increases.

Following this reasoning, we should expect the percentage of rainfall intercepted to be less for heavy rain than for light rains. Zon states this to be a fact (*a*) (**10**) but he does not give any data in support of his conclusions. Most of the data hitherto published in the form in which presented are quite doscordnat as regards the relation of rainfall intensity to amount of interception, but this is quite certainly due in part to the presentation of results in monthly or seasonal totals regardless of rainfall distribution.

THE CHARACTER OF INTERCEPTION STORAGE ON DIFFERENT PLANTS.

Observation and sketches were made of the amount of water accumulated on different plant surfaces after a rainfall on July 12, 1915, of 0.12 inch at night, with no wind. Sketches of typical leaves, showing the mode of water storage or accumulation thereon, are contained in the accompanying fig. 2.

Leaves of different plants vary greatly in the manner in which rain falling on them is retained. Many leaves become wetted over their entire upper surface with a thin film of water which is not shown in the sketches. There does not seem to be any regular rule as to this, as leaves which appear bright and waxy as well as others having dull surfaces both become wetted in some cases, whereas in other cases, according to the configuration of the surface of the leaf, water accumulates on both classes of leaves only in drops or blotches. Of course, water tends to accumulate in capillary spaces of all forms. In some cases where the entire leaf surface becomes wetted the film thickens in the depressions along the lines of the veins. More generally the entire leaf surface does not become wetted, and in such cases the water which accumulates in drops on the leaf surfaces is mostly concentrated on the plateaus or ridges between the lines of veins. Apparently the majority of leaves do not become appreciably wetted on the underside, excepting where drops and blotches overflow from the edges.

The possibilities of interception storage are revealed by observations by the author on July 12, 1915, of more than 100 water drops retained per leaf on leaves of horse-chestnut, oak, and aspen, in addition to blotches and films, and 100 or more drops on single stems of rye.

During the defoliated season the author has observed large drops about 1 inch apart clinging after a cold rain to the underside of every twig or horizontal branch of a maple. In warm weather this water runs off more easily and the interception storage is then largely on leaf surfaces.

An approximate estimate of the interception storage can be arrived at by counting the number of drops per unit of plant surface, estimating their diameter and volume.

Volumes of small spheres per million

Diameter.	Volume per million.
In inches.	*Cubic inches.*
1/32	15.98
1/16	127.83
3/32	450.40
1/8	1,022.60
5/32	2,085.00
3/16	3,451.40
7/32	5,721.20
1/4	8,181.20

For example, a crop of rye containing 3,000 stalks per acre, with storage equal to one hundred and twenty ⅛-inch drops per stalk, would contain, exclusive of water in the heads, 213.1 cubic feet of interception storage per acre. This is equivalent to a depth of 0.047 inch on the surface.

Again, a tree having one-half million leaves, with an average of twenty ⅛-inch diameter drops per leaf, would contain 5.92 cubic feet of interception storage. If the crown diameter was 40 feet, the projected area being 1,256 square feet, the interception storage would be equivalent to 0.0564 inch.

EXPERIMENTAL DATA OF INTERCEPTION.

In order to determine the numerical factors for calculating interception losses, an effort was first made to utilize existing experimental data. For this purpose, the interception records for the Adlisberg and Haidenhaus forest meteorological stations were analyzed for the years 1889 and 1890. The recorded precipitations on each day when rain fell were grouped together according to the amount of precipitation at the station in the open, averages for each group were taken both for the station in open and for stations in the forest.

TABLES 2, *A*, *B*, *C*.—*Analysis of Adlisberg records precipitation arranged by daily amounts caught by gage in open, in inches.*

Range mm. per day.	Average inches per day.	Beech (1).	Beech (2).	Beech (3).	Average beeches (2) and (3)
(1)	(2)	(3)	(4)	(5)	(6)
B—BEECHES, SUMMER PERCENTAGES CAUGHT.					
0–15	0.10	[1] 92.80	77.30	79.60	78.45
5–10	.30	95.51	78.59	83.91	81.25
10–20	.60	93.41	80.50	87.50	81.00
Over 20	.90	86.20	80.44	85.30	[2] 82.37
A—BEECHES, WINTER PERCENTAGES.					
0–5	0.10	97.30	72.05	80.43	71.24
5–10	.30	100.00	64.15	68.27	66.21
10–20	.60	70.63	42.25	51.88	47.06
Over 20	.90	87.51	....	....	....
C—FIRS, PERCENTAGES CAUGHT.					
		Winter.	*Summer.*		
0–5	0.10	42.95	52.50	....	....
5–10	.30	44.65	68.90	....	....
10–20	.60	54.76	81.10	....	....
Over 20	.90	75.74	79.80	....	....

[1] For full two-year period. [2] Number of observations small.

Winter and summer records were separated, the six months period, November to April, inclusive, being counted as winter. Tables No. 2, A, B, and C contain a summary of these studies. The results for fir trees, Table 2 C, show a fairly consistent increase in the percentage of precipitation reaching the ground as the rainfall in inches per day increases. This is true in the case of fir for both winter and summer conditions. In the case of beech trees, one station was maintained throughout the whole period, and two additional stations during the year 1890.

Station No. 1 for beech, which covers the entire period, shows in the case of many storms a measured precipitation greater than that in the open. The average percentage of rainfall reaching the ground for station No. 1 under beech is indicated in column (2) of Tables 2 B and 2 A, respectively. It will be noted that the percentage reaching the ground under beech, station No. 1, is much larger than the percentage reaching the ground under beeches Nos. 2 and 3, and this is indicated by columns (3) and (4) of the same tables.

If station No. 1, for beech, is included, the average for the three stations does not show any consistent relation between rainfall intensity and amount of interception loss. Excluding station No. 1, the record for beeches shows a fairly consistent but small increase in the percentage of rainfall reaching the ground, with increased rainfall rate during the summer season, as indicated by column (5) of Table 2 B. The results fail, however, to show a consistent increase; and show, in fact, a consistent apparent decrease in percentages for the mean of beech at stations Nos. 2 and 3, for winter conditions. In

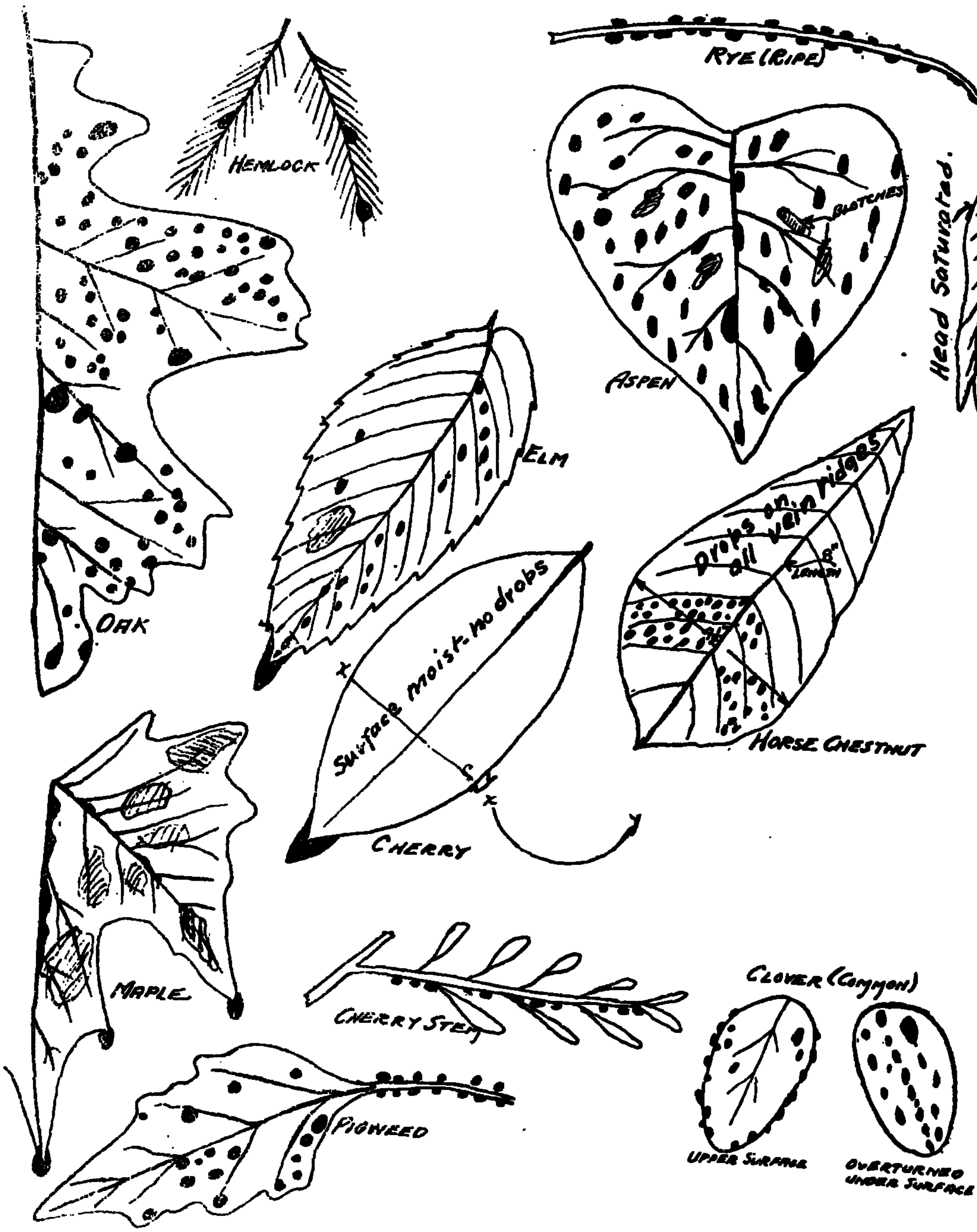

FIG. 2.—Interception storage on various plants.

general it appears that the *a priori* conclusion is fairly confirmed by these experiments as well as could be expected, taking into account the evident large experimental errors existing.

Interception by beech crowns of different ages (Bühler).

	Age of stand, years.			
	20	50	60	80
Proportion reaching ground	0.98	0.73	0.77	0.83
Proportion intercepted	.02	.27	.23	.17

Taking the Adlisberg records by months, arranged in order of magnitude by rainfall rates, we find, for the summer, the following:

TABLE No. 3.—*Monthly precipitation caught under trees, per cent of that in the open, Adlisberg.*

Inches.	Days.	Rate.	Per cent caught.				
			Fir.	Beech (1).	Beech (2).	Beech (3).	Mean, Beech (2) and (3).
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
2.23	20	0.111	57.2	90.7	73.4	78.5	75.9
4.33	20	.217	77.2	107.2	77.5	89.4	83.4
4.21	17	.240	72.6	94.0	75.4	83.0	79.2
5.08	14	.360	95.2	87.0	82.6	85.8	84.2
1.47	4	.370	90.2	96.0	82.6	97.6	90.2
9.42	19	.480	78.6	94.4	74.9	80.0	77.5

This table shows a general tendency to increase in percentage of rainfall caught by gage in forest as rainfall rate increases. The same is true at Haidenhaus, as indicated by Table No. 4.

The Adlisberg and Haidenhaus records both show an apparent decrease in percentage caught in the forest in winter as the rate per storm increases.

TABLE No. 4.—*Haidenhaus interception data; analysis of monthly records on basis of average rainfall rate per storm day.*

Precipitation in open.			Precipitation in forest, per cent of open.	
Inches.	Days.	Inches per day.	Deciduous.	Evergreen.
(1)	(2)	(3)	(4)	(5)
WINTER.				
0.18	3	0.06	102.2	22.2
1.16	11	.105	86.8	56.2
1.33	3	.11	157.0	78.0
2.62	22	.12	73.4	26.3
3.02	17	.17	80.2	53.7
SUMMER.				
2.65	18	0.146	61.7	42.8
4.73	21	.225	70.2	45.6
1.55	6	.26	70.3	57.6
4.89	15	.326	70.0	56.0
5.36	13	.41	71.0	62.8
9.30	20	.46	77.2	58.2

THE AUTHOR'S EXPERIMENTS ON INTERCEPTION.

The data of interception thus far reviewed are in the form of annual, monthly, or, at best, daily averages. Published data of rainfall interception in individual showers are meager. The following observations were made by Seckendorff during a continuous downpour of rain, which lasted from the morning of June 12th to the night of June 14th. The total precipitation was 52.6 millimeters (2.07 inches).[1]

Interception of rainfall by trees.

Tree.	Precipitation in inches.	Percentage reaching ground.	
		Not including water running down tree trunk.	Including water running down tree trunk.
Beech	2.07	54.0	61.6
Oak	2.07	62.5	68.9
Maple	2.07	65.2	69.4
Pine	2.07	30.6	31.6

In order to provide data for analysis on the basis of individual showers the experiments described below were carried out.

TABLE 5.—*Summary of Ebermayer's experiments on rainfall interception.*

Station.	Forest.	Precipitation in open, inches per month.		Percentage caught in forest.		Loss per cent.		Precipitation in forest.	
		Winter.	Summer.	Winter.	Summer.	Winter.	Summer.	Winter.	Summer.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Seeshaupt	40-year-old fir	2.55	3.28	68.6	76.2	41.4	23.8	1.75	2.50
Duschelberg	40-year-old pine	6.79	2.73	73.6	72.5	26.4	27.5	5.00	1.98
Ebrach	50-year-old pine	2.86	1.61	90.6	69.6	9.4	30.4	2.59	1.12
Altenfurth	Wild pine	2.34	1.83	75.4	68.9	24.6	31.1	1.765	1.26
Mean, evergreens		3.64	2.36	77.05	71.8	22.95	28.2	2.78	1.72
Johanneskreutz	60-year old beech	3.49	3.16	72.5	79.0	27.5	21.0	2.53	2.50
Rohrbrunn	60-year-old beech	4.04	2.96	80.0	82.4	20.0	17.6	3.23	2.44
Mean, beech		3.76	3.06	76.25	80.7	23.75	19.3	2.88	2.47

[1] Lueger, Wasserversorgung der Städte.

During the period July to November, inclusive, 1917, and April to October, inclusive, 1918, interceptometers were maintained under trees of various kinds at the hydrologic laboratory of the author near Albany, N. Y. The accompanying map, fig. 3, shows the positions of the different trees and the accompanying Table No. 6 gives the size of each tree and other details. The rain gages used as interceptometers were galvanized iron pans, each 17 inches in diameter and 5 inches deep. A ½-inch pipe nipple was secured in the bottom of each pan near the side, the pan was supported at a height of about 1 foot above ground, and the nipple was inserted in the neck of a 1-gallon glass bottle. Under the major portions of the crowns of the trees there was complete leaf cover, but varying in thickness or density. The interceptometers were placed as nearly as possible under complete leaf-cover of average thickness.

Duplicate interceptometers were placed under maple, horse-chestnut, and elm trees, one in each case being near the trunk or about midway between the trunk and periphery of the tree, the other being just within the periphery. The peripheral interceptometers probably received direct rainfall rather than drippings from the tree, especially in the case of the elm, as the branches of this tree were 15 feet or more above ground, and the tree was in an exposed position, with the interceptometer on the south side, so that rains from the south or southwest falling at an angle with the wind could not be prevented from entering the gage directly.

In order to compare the catch by the interceptometers with that from an ordinary rain gage, a check interceptometer was maintained in the instrument inclosure alongside of a Friez tipping-bucket rain gage. This interceptometer gave readings practically identical in all cases with those obtained from the Friez rain gage.

A triangle of 3 rain gages was used, the rain gages being in the positions indicated on the map (fig. 3). There were nearly always slight differences in the amounts of rain caught by these gages, and in reducing the interceptometer results the rainfall on the tree crown has been taken as equal to that indicated by the mean of the three gages, although it is possible that a somewhat more accurate result might have been obtained by applying the results of a given rain gage to the records from trees to which the given rain gage stood nearest. The interceptometers were read in each instance as soon as practicable after the rain ceased, usually within an hour or two at most. Measurements were not, however, taken for each temporary cessation of rainfall. If, for example, two showers occurred separated by a rainless interval of not to exceed one hour, the rainfall for both showers was included in a single measurement.

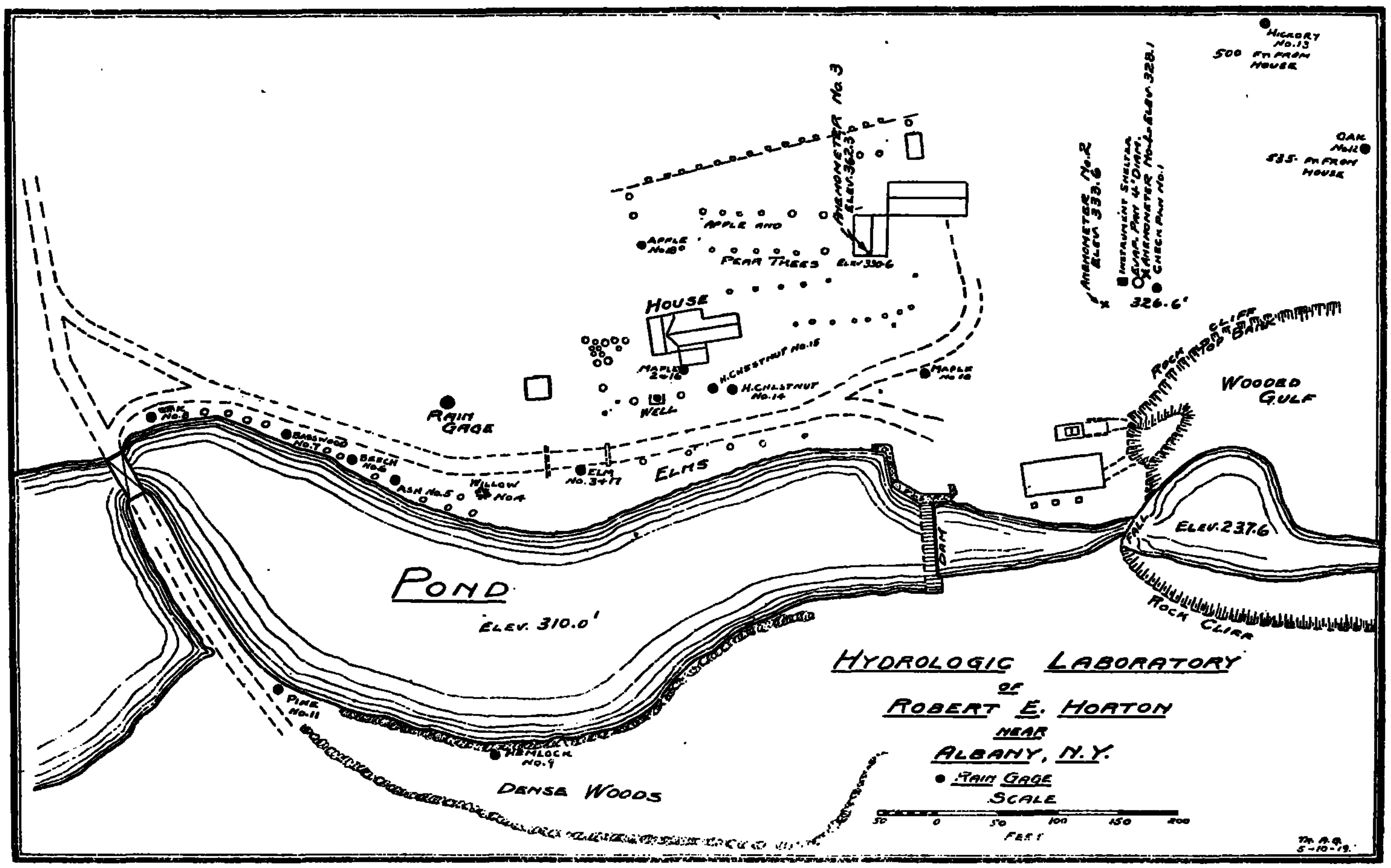

FIG. 3.—Map of author's hydrologic laboratory near Albany, N. Y.

The accompanying photographs, figures 4 to 9, inclusive, show several of the interceptometers and the trees in conjunction with them.

During the early part of 1917 the depths in the interceptometer bottles were measured with a rain-gage stick, the bottles having been previously calibrated by weighing. Later the water caught in the bottles has been measured in a calibrated can. The number of canfuls and the fraction of a canful, measured with a rain-gage stick, were recorded in each instance. The can was carefully calibrated for different depths by weighing on an accurate torsion balance. This method of measuring the water

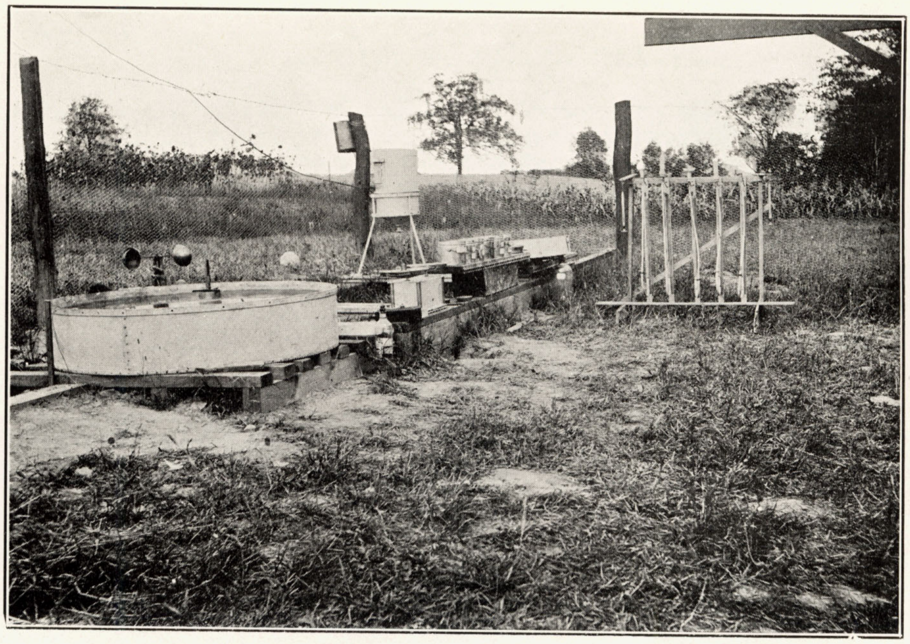

Fig. 4.—Evaporation station and check pan.

Fig. 5.—Interceptometer under hemlocks.

Fig. 6.—Interceptometer under willow shrubs.

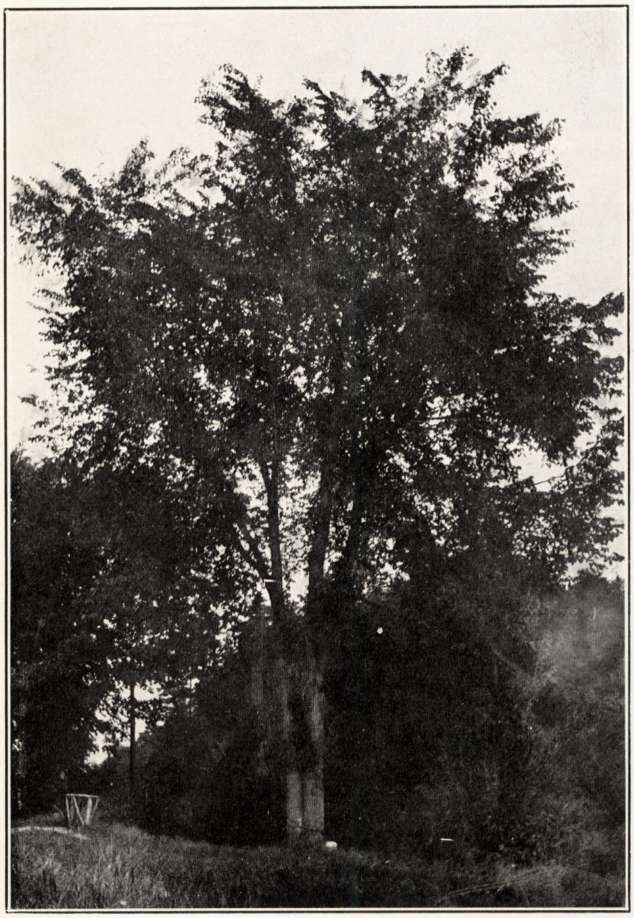

FIG. 7.—Interceptometer under elm.

FIG. 8.—Interceptometer under elm, near view.

FIG. 9.—Interceptometer under ash, beech, and basswood.

caught in the tree-trunk tubs has been used throughout the work.

TABLE No. 6.—*Data for interceptometers.*

Pan No.	Tree.	Diameter of trunk.	Height.	Interceptometer to trunk C to C (A).	Interceptometer to periphery (B).[1]	Projected area.	Depth on area of 2 quarts =115.5 cubic inches.
		Feet.	*Feet.*	*Feet.*	*Feet.*	*Sq. ft.*	
1	Test gage						
2	Maple (house)	1.00		1½ sw	14	620	0.00130
3	Elm	1.95	55	8 se	13	1,240	.00065
4	Willow			1½ s	2	64	.01250
5	Ash	1.95		4½ n	18	1,320	.00061
6	Beech	.70		4½ ne	{7, 14}	200	.00401
7	Basswood	.75		8 n	{0, 7}	240	.00335
8	Oak	2.90	30	5 nw	14	625	.00128
9	Hemlock	1.40	42	5 se	9	350	.00229
10	Maple	.60	47	4 s	6½	285	.00282
11	Pine	2.10	65	4 n	13	1,035	.00078
12	Oak	2.40	65	12 sw	13	1,440	.00056
13	Hickory	1.45	50	6½ sw	11	950	.00085
14	Horse chestnut	1.90		13 ne	2½	780	.00103
15	....do	1.40		3 nw	12	435	.00185
16	Maple (house)	1.00		10.5 sw	5	620	.00130
17	Elm	1.95	55	12 s	9	1,240	.00065
18	Apple	1.85	30	5½ ne	13	845	.00095

[1] Where two values are given the greater one is to outside edge of foliage. Smaller one is to edge of foliage draining to trunk.

WATER RETURNED BY TREE TRUNKS.

In this study the data cited thus far relate to interception by tree crowns alone. In many instances, some portion of the intercepted water runs down the tree branches and trunk and so ultimately reaches the ground. The total interception loss by trees was determined by Riegler at Nancy by the use of gages of the same area as the tree crown, arrangements being made to include in the catch of the gage the part of the rainfall which flowed down the trunk. Riegler's experiments cited by Harrington have been reduced to percentages, and are presented in Table No. 7. These experiments also indicate the small differences in interception by various kinds of broad-leaved trees. The portion of the intercepted rainfall which reaches the ground by way of the tree trunk is apparently much smaller for evergreen than for broad-leaved trees. Zon states that the percentage of the total rainfall passing down the tree trunk varies from 0.7 of 1 per cent to 3 per cent for evergreens, and may be as high as 15 per cent for broad-leaved trees.

TABLE No. 7.—*Riegler's experiments on interception by trees.*

[Rain falling on tree crown=100 per cent.]

	Rain falling through crown on soil.	Rain running off trunk.	Total per cent reaching soil.	Loss per cent.
(1)	(2)	(3)	(4)	(5)
Beech	65.4	12.8	78.2	21.8
Oak	73.6	5.7	79.3	20.7
Maple	71.5	6.0	77.5	22.5
Spruce	39.8	1.4	41.2	58.8

NOTE.—Rain gage equal in area to tree crown. Results for spruce void, because part of rain ran off tips of outward inclined branches and was not caught by gage.—Harrington, Forest Influences, p. 133.

In order to determine the amount of water running down the trunks of trees, in the author's experiments, a small lead trough was constructed around each tree trunk, as shown on fig. 10. The troughs were made of lead flashing about one-sixteenth inch thick, cut into strips 2½ inches wide. The strip was first rolled while straight into approximately the form shown in the cross-section B, figure 10. The straight trough was filled with sand to preserve its form, and was wound around a prepared portion of the tree trunk, usually about 2 feet above ground. The tree trunk was prepared by removing rough scales and smoothing down the bark, care being taken not to make any deep incisions which would injure the tree. The trough was first tacked to the tree on the side opposite the pan, about midlength of the trough, then each end was carefully wound around to the opposite side in such a manner as to give the trough a slight inclination. The wider side of the trough which rested against the tree was nailed at various points with small nails, and the edge of the lead caulked as tightly as possible into all crevices and irregularities in the trunk.

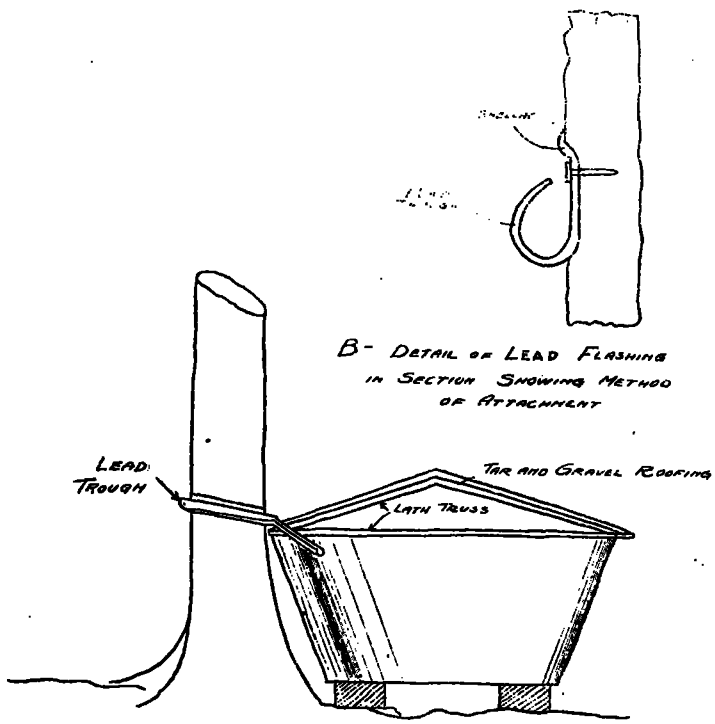

FIG. 10.—Typical tree-truck interceptometer with section of tub and cover.

The sand was then removed from the trough, the shorter end was bent over and into the longer projecting end of the trough, and the longer end was bent down so as to convey the water into the catch pan.

In 1917 melted paraffin was used to secure a watertight joint between the upper edge of the lead and the bark of the tree. This would work well for a while, but afterwards would scale off, requiring frequent renewal to prevent leakage.

During 1918 several coats of thick shellac were used instead, with better results. The outside edge of the trough was bent over so as to leave an opening about one-fourth of an inch wide so as to prevent direct rainfall entering the trough in any considerable quantity. Covered 5-gallon galvanized pails were first used to catch the run-off, but it was found that for nearly all trees these would overflow, in a rain of a half inch or more, and large galvanized iron wash tubs were substituted, these tubs having a capacity of about 35 gallons each. Even then in some cases the tubs under certain trees would overflow during very heavy rains.

To prevent direct rainfall entering the tubs, and also to reduce evaporation, covers were made by constructing a light truss work of lath on which heavy tar and graveled roofing paper was tacked, thus providing a light, strong roof with inclination sufficient to carry the rain off readily, the roofing paper being lapped over the lead trough where the latter passed over the edge of the tub. The covers are held in position by weights and wires.

Early in the investigation it was found that there were surprisingly large variations in the amount of water caught in the tubs under different trees, and it soon became evident that smooth bark trees carry relatively large quantities of water down their trunks, while shag dark color, that from pine and hemlock being nearly as black as molasses.

The volume of water caught from the trunk of a large smooth bark tree in a heavy shower was often 20 to 30 gallons. How this occurs is esily understood when one considers than a film 0.01 inch thick flowing down the trunk of a tree 3 feet in circumference at 10 feet per minute amounts to 216 cubic inches per hour. As the results subsequently given show, the water running down the tree trunks, when reduced to equivalent depth on the projected area of the tree crown, is relatively slight, as appears from Tables Nos. 8 and 9, which show the amounts of precipitation caught by the tree trunk interceptometers,

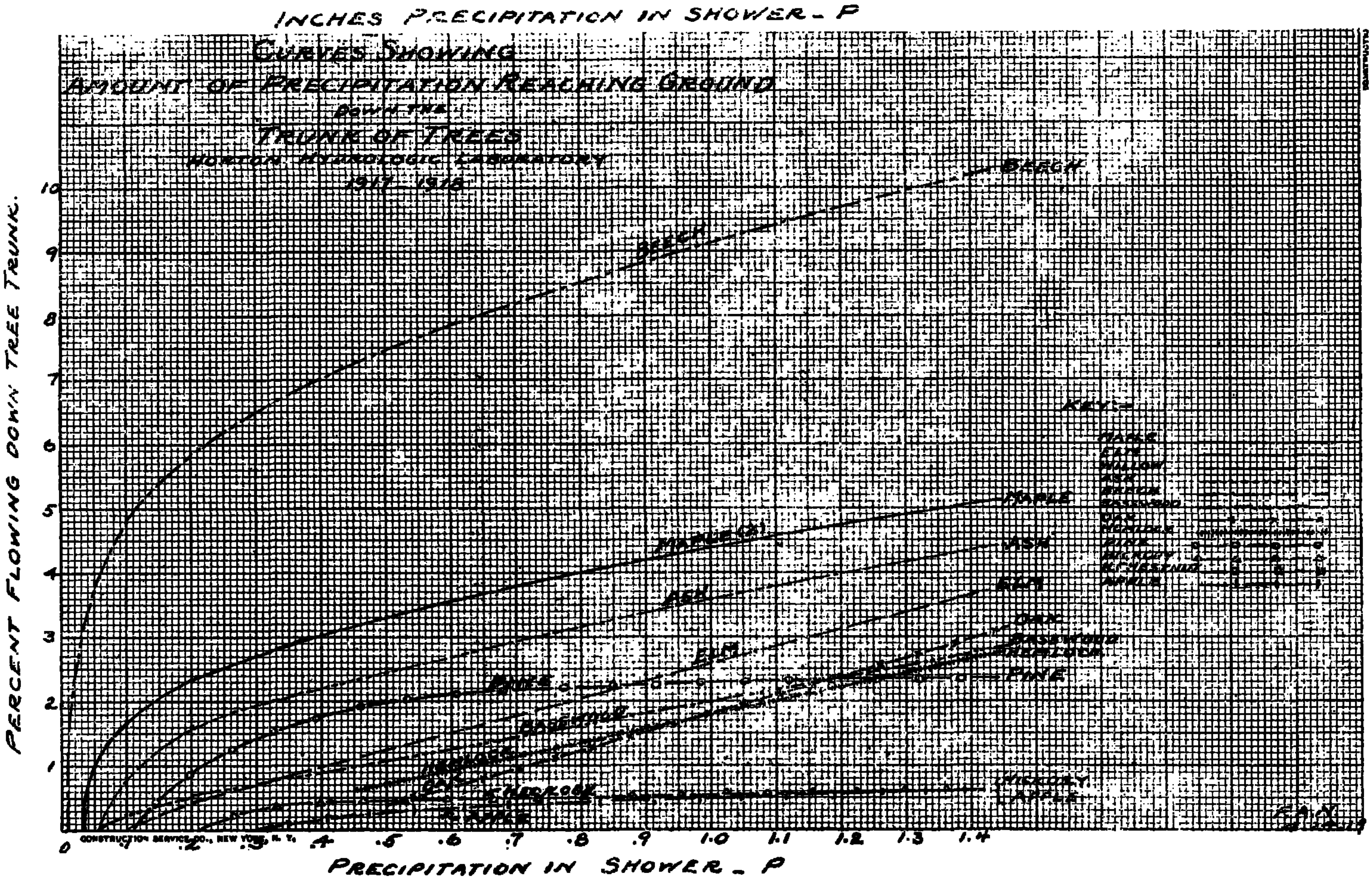

FIG. 11.—Summary of curves showing the amount of precipitation reaching ground down the tree trunks.

bark hickories, oaks, pines, and hemlocks permit but little water to pass down the trunks of the trees.

Since the trees stood in the open or in hedges they were more exposed than similar trees in a dense forest. In the case of a rain with driving wind, striking the exposed side of the tree, it is probable that a not inconsiderable portion of the water running down the trunks resulted from rain which struck the trunks directly, whereas, in the case of trees in dense forests this would not occur to any great extent. Close observation of the trees, and comparison of the results in rains which descended vertically and in strong winds indicate that this condition, while marked in some rains, does not usually prevail, and it may be safely assumed that nearly all the water running down the trunks would also have run down the trunks of trees in the forest. In nearly all cases, the water running down the tree trunks was of exceedingly

TABLE 8.—*Summary of amount of water in inches of precipitation flowing down trunk of tree for storms of various magnitudes.*

Number showers.	Kind of tree.	Precipitation (inches.)					
		0-0.05	0.05-0.10	0.10-0.30	0.30-0.60	0.60-1.0	1.0-2.0
2	Maple	T.	0.001	0.005	0.014	0.038	0.078
10	....do	T.	.001	.004	.010	.020	.053
3	Elm	T.	T.	.001	.004	.014	.042
17	....do						
4	Willow						
5	Ash	T.	T.	.003	.010	.017	.052
6	Beech	.001	.003	.011	.028	.064	.127
7	Basswood	T.	T.	.001	.003	.008	.032
8	Oak						
12	....do	T.	T.	T.	.001	.005	.033
9	Hemlock	T.	T.	.001	.002	.007	.030
11	Pine	T.	T.	.001	.008	.019	.027
13	Hickory	T.	T.	T.	.002	.004	.007
14	Horse-chestnut						
15	....do						
18	Apple	T.	T.	T.	.001	.003	.007

TABLE No. 9.—*Summary of amount of water in per cent of total precipitation per shower flowing down trunk of tree for storms of various magnitudes.*

Number showers.	Kind of tree.	Precipitation in shower (inches). 0-0.05	0.05-0.10	0.10-0.30	0.30-0.60	0.60-1.0	1.0-2.0
2	Maple	T.	1.5	2.7	3.3	5.2	6.1
10	.....do	T.	1.5	2.2	2.4	2.5	3.8
	Mean	T.	1.5	2.4	2.8	3.8	5.0
3	Elm	T.	T.	0.5	1.0	1.9	3.3
5	Ash	T.	T.	1.6	2.4	2.5	4.1
6	Beech	3.2	4.5	6.0	6.7	8.5	9.9
7	Basswood	T.	T.	0.6	0.7	1.3	2.5
12	Oak	T.	T.	T.	0.2	0.7	2.6
9	Hemlock	T.	T.	0.6	0.5	0.9	2.4
11	Pine	T.	T.	0.6	1.9	2.5	2.2
13	Hickory	T.	T.	T.	0 5	0.5	0.6
18	Apple	T.	T.	T.	0.2	0.4	0.6

Smoothed curves of these results are given on figure 11. In general the rough bark trunks conduct the least water to the ground, and in the case of apple, shag bark hickory, oak and hemlock very little rain runs down the trunks in showers of less than 0.2 to 0.3 inch. The curves are generally of parabolic form, showing a smaller percentage running down the tree trunks in light than in heavy showers.

TOTAL INTERCEPTION LOSS AS A PERCENTAGE OF THE PRECIPITATION PER SHOWER.

In working up the experimental records, data were tabulated in groups, each group including showers for which the precipitation fell between assigned limits. The group means for the different showers and interceptometers are contained in Table No. 10.

TABLE 10.—*Analysis of 1917–1918 interceptometer records.*

[Horton Hydrologic Laboratory, Voorheesville, N. Y.]

Tree.		Precipitation, 0-0.05.				Precipitation, 0.05-0.10.				Precipitation, 0.10-0.30.				Precipitation, 0.30-0.60.				Precipitation, 0.60-1.0.				Precipitation, 1.0-2.0.			
No.	Kind of tree.	Number of showers.	Amount of precipitation.	Duration of rain.	Loss.	Number of showers.	Amount of precipitation.	Duration of rain.	Loss.	Number of showers.	Amount of precipitation.	Duration of rain.	Loss.	Number of showers.	Amount of precipitation.	Duration of rain.	Loss.	Number of showers.	Amount of precipitation.	Duration of rain.	Loss.	Number of showers.	Amount of precipitation.	Duration of rain.	Loss.
			In.	Hrs.	In.		In.	Hrs.	In.		In.	Hrs.	In.		In.	Hrs.	In.		In.	Hrs.	In.		In.	Hrs.	In.
2	Maple	12	0.031	0.71	0.026	18	0.067	1.18	0.012	31	0.18	2.18	0.063	17	0.418	3.63	0.123	5	0.724	6.31	0.170	2	1.278	8.70	0.262
10	.....do	5	.034	1.13	.027	12	.065	1.27	.014	20	.185	2.40	.093	12	.416	4.11	.188	3	.806	8.06	.42	2	1.410	5.12	.504
16	.....do.[1]	3	.043	1.15	.018	12	.065	1.27	.035	17	.187	2.33	.057	12	.416	4.11	[2]—.016	5	.725	6.31	.095	1	1.257	10.91	.735
	Mean	......	.036	1.00	.024	......	.066	1.2[illegible]	.040	......	.185	2.30	.071	......	.417	3.95	.098	......	.752	6.89	.230	......	1.315	8.24	.500
3	Elm	12	.031	0.71	.025	18	.067	1.18	.053	31	.18	2.18	.083	17	.418	3.63	.139	5	.724	6.31	.189	1	1.257	10.91	.187
17	.....do.[1]	2	.043	0.24	.018	12	.065	1.27	.039	18	.192	2.28	.066	11	.417	4.43	.070	4	.755	6.71	.074	......	......	......	......
	Mean	......	.037	0.48	.022	......	.066	1.22	.0[illegible]6	......	.188	2.23	.075	......	.418	4.03	.10[illegible]	......	.740	6.51	.131	......	1.257	10.91	.187
4	Willow [3]	12	.031	0.71	.024	18	.067	1.18	.0[illegible]6	31	.184	2.18	.087	17	.418	3.63	.172	5	.724	6.31	.367	2	1.278	8.70	.564
5	Ash	12	.031	0.71	.011	18	.067	1.18	.028	31	.18	2.18	.019	17	.418	3.63	[2].105	4	.694	5.57	.262	2	1.278	8.70	.268
6	Beech	12	.031	0.71	.023	18	.067	1.18	.035	31	.18	2.18	.061	17	.418	3.63	.130	4	.755	7.21	.121	2	1.278	8.70	.316
7	Basswood [3]	9	.027	0.52	.022	6	.070	0.98	.035	13	.173	2.07	[2].016	5	.42	2.51	[2]—.005	1	.603	4.68	.215	1	1.257	10.91	[2]—.028
8	Oak [3]	9	.027	0.52	0.25	6	.070	0.98	.053	13	.173	2.07	.073	5	.42	2.51	.177	1	.603	4.68	.319	1	1.257	10.91	.340
12	.....do	5	.034	1.13	[2].002	12	.065	1.27	.042	20	.185	2.40	.051	12	.416	4.11	.050	4	.755	7.22	.121	1	1.257	10.91	.396
	Mean	......	.030	0.82	.014	......	.068	1.12	.018	......	.179	2.23	......	......	.420	3.31	.113	......	.679	5.95	.220	......	1.257	10.91	.368
9	Hemlock	11	.032	0.67	.022	18	.067	1.18	.056	28	.180	2.22	.088	16	.417	3.79	.105	4	.755	7.21	.188	1	1.257	10.91	.489
11	Pine	11	.032	0.67	.023	18	.067	1.18	.055	28	.180	2.22	.089	16	.417	3.79	.151	4	.755	7.22	.114	1	1.257	10.91	.026
13	Hickory	5	.034	1.13	[2].003	11	.066	1.32	.018	20	.185	2.40	[2].011	12	.416	4.11	[2]—.0.0	4	.755	7.22	[2].059	1	1.257	10.91	[2]—.125
14	Horsechestnut [1,3]	5	.034	1.13	.022	12	.065	1.27	.013	20	.185	2.40	[2].058	12	.416	4.11	.111	5	.725	6.31	.083	1	1.300	6.50	.345
15	.....do.[3]	5	.034	1.13	.024	12	.065	1.27	.041	20	.185	2.40	.088	12	.416	4.11	.160	5	.725	6.31	.270	1	1.300	6.50	.493
	Mean	......	.034	1.13	.023	......	.065	1.27	.042	......	.185	2.40	.073	......	.416	4.11	.135	......	.725	6.31	.176	......	1.300	6.50	.419
18	Apple	5	.034	1.13	.018	12	.065	1.27	.041	20	.185	2.40	.076	12	.416	4.10	.106	4	.755	7.22	.176	1	1.257	10.91	.349
	Mean of all	......	.033	0.83	.020	......	.066	1.20	.043	......	.183	2.26	.067	......	.418	3.76	.102	......	.726	6.52	.191	......	1.277	9.44	.320
	Mean of all except Nos. 4, 7, 8, 14, and 15	......	.034	0.81	.018	......	.066	1.23	.013	......	.185	2.28	.068	......	.417	3.92	.093	......	.746	6.88	.166	......	1.277	9.78	.310
	Mean of all except Nos. 14, 16, and 17	......	.032	0.83	.020	......	.067	1.19	.044	......	.182	2.25	.068	......	.417	3.66	.111	......	.724	6.54	.214	......	1.277	9.55	.289

[1] Near periphery of tree cover.
[2] Mean is low due to few large negative results.
[3] Trees for which trunk water was not collected and for which correction has been made.

Table No. 11 shows the same results, in condensed form, and reduced to the basis of percentages of the total precipitation per shower which was lost or intercepted, corrected for rain running down the tree trunks. The average loss ranges from 70 per cent of the total in very slight showers, to about 24 per cent in heavy, long-continued rains

TABLE No. 11.—*Summary of interceptometer records showing amount of water lost to ground by tree interception.*

Tree.		Percentage of precipitation lost.					
No.	Kind of tree.	0-0.05	0.05-0.10	0.10-0.30	0.30-0.60	0.60-1.0	1.0-2.0
2	Maple	83.8	62.7	34.2	29.4	23.5	20.5
10	....do	79.4	67.7	50.3	45.2	52.6	35.7
16	....do. [1]	41.8	54.0	30.5	([2])	13.1	58.5
	Mean Nos. 2 and 10	81.6	65.2	42.2	37.3	38.0	28.1
3	Elm	80.6	79.1	45.1	33.3	26.1	14.9
17	....do. [1]	41.8	60.0	34.4	16.8	9.8	....
	Mean	61.2	69.6	39.8	25.0	18.0	14.9
4	Willow [3]	77.4	68.7	47.3	41.1	50.6	44.1
5	Ash	35.5	41.8	26.6	[2] 25.1	37.7	21.0
6	Beech	74.2	52.2	33.1	31.1	16.0	24.7
7	Basswood [3]	81.5	50.0	([2])	([2])	35.6	([2])
8	Oak [3]	92.5	75.7	42.2	41.8	52.8	27.1
12	....do. [3]	([2])	64.7	27.6	12.0	16.0	31.5
	Mean [3]	....	70.2	34.9	26.9	34.4	29.8
9	Hemlock	68.7	83.6	48.9	25.2	24.9	38.9
11	Pine	71.9	82.1	49.5	36.2	15.1	2.1
13	Hickory	([2])	72.7	[2] 22.2	([2])	[2] 7.8	([2])
14	Horse chestnut [1 3]	64.7	66.2	[2] 31.4	26.7	11.4	26.5
15	....do. [3]	70.5	63.1	47.6	38.5	37.2	37.9
	Mean [3]	67.6	61.6	39.5	32.6	24.3	32.2
18	Apple	52.9	63.1	41.1	25.5	23.3	27.8
	Mean of all	70.5	65.1	38.2	39.5	26.7	29.4
	Mean of all except 4, 7, 8, 14, 15, 16, 17	68.4	67.0	37.6	29.6	24.6	24.3

[1] Near periphery of tree cover.
[2] Percentage too small: Too many negative results involved in one mean.
[3] Not corrected for water running down the trunk: all others are corrected.

Figure 12 shows the percentage loss for all trees, on a comparative basis. In general, with regard to all the curves, the plotted points are very consistent for smaller amounts of rainfall where the number of observations included in a group mean was relatively large. There were several showers of less than 0.05 inch rain, in which nothing was caught in the interceptometers, and which showers were not included in making out the group means. The effect of including these would be to make the percentage interception for rainfall amounts of less than 0.05 inch somewhat larger. The low loss for heavy showers in the case of the hickory and elm, especially the former, is undoubtedly due to the exposure of the trees and the height of the crown above ground. As a result of these conditions, the interceptometers received direct precipitation in some showers, accompanied by wind blowing from the same side of the trees as that on which the interceptometer was placed. The curves are in general hyperbolic in form, and could be expressed by formulae of the type

$$\text{Per cent loss} = a + \frac{b}{P}$$

in which a and b are constants, and P is the amount of precipitation per shower. Here a represents interception storage depth, and $a+b$ is the ordinate of the asymptotic line, which the curve approaches as the amount of precipitation increases indefinitely. In other words, the interception loss approaches a constant percentage of the total precipitation in very heavy rains.

Figure 13 is an average of all the curves, expressed in a similar manner.

INTERCEPTION DEPTH ON PROJECTED TREE-CROWN AREA PER SHOWER.

In figure 14, the results are shown graphically in terms of the amount of precipitation loss over the projected area of the crown of the tree.

Figure 15 is the mean of the curves shown on figure 14. This is a straight line, except near the origin, and would be apparently a straight line throughout but for the fact that in very light showers, less than sufficient to satisfy the interception storage, some of the rain may be shaken off the trees by the wind.

The amount of interception storage for each tree is approximately determined by extending the line or curve on figure 14 to the zero precipitation line, in the direction determined by the portion of the curve plotted for rains exceeding the interception storage. For rains less in amount than the average interception storage, the interception loss would be in general 100 per cent, if there were no wind, but may be less, if a portion of the storage remaining on the tree at the end of the shower is shaken off by the wind.

The accompanying formulæ show the average interception, corrected for water running down the trunks of the trees, expressed in terms of precipitation per shower. In the linear formulæ the first constant represents the interception storage and the second the limiting minimum proportion of the rain lost as the amount per shower increases.

Summer season interception per shower by various trees.

$J=0.015+0.23\ P_s$ .... Ash.
$J=0.04+0.18\ P_s$ .... Apple.
$J=0.04+0.20\ P_s$ .... Horse-chestnut.
$J=0.02+0.23\ P_s$ .... Beech.[1]
$J=0.03+0.22\ P_s$ .... Oak (mean).
$J=0.03+0.23\ P_s$ .... Maple.
$J=0.23\ P_s^{1/2}$ .... Elm (No. 3).[2]
$J=0.13\ P_s^{1/2}$ .... Basswood.
$J=0.20\ P_s^{1/2}$ .... Hemlock and pine.
$J=0.02+0.40\ P_s$ .... Willow shrubs.[3]

The formulas apply only when P is greater than the constant, otherwise $J=P$, nearly.

In deriving these formulæ, results obtained by peripheral interceptometers have been disregarded for reasons elsewhere stated. It will be noted by reference to figure 12 that the interception loss for oak, maple, ash, beech, and horse-chestnut are very nearly the same, and an average formula for these trees may be used. In the case of all except the hemlock, pine, and elm trees, the interception curves either in terms of precipitation per shower, or shower duration are straight lines. In the case of the hemlock, pine, and elm, the curves both in terms of amount and duration are parabolic in form. In the case of the pine and hemlock, the bark and leaves seem to absorb a relatively large amount of precipitation as hygroscopic moisture.

The relatively large loss by interception from willows, which in this case were shrubs of 8 to 10 feet in height, is notable. This loss greatly exceeds that for other trees, except the basswood, even after correction for water running down the trunks, which correction in the case of the willow shrubs was estimated from the data for other trees.

The following Table No. 12 shows the mean precipitation in each shower and the mean loss per shower for each kind of tree.

The inaccuracy of using average percentages in calculating interception losses in individual cases is illustrated by the following example. The average precipitation per shower during the 78 experiments on pine was 0.22 inch, and the average interception loss from the

[1] Tree crown partly defoliated.
[2] Apparently deficient for storage, because of high crown and direct catch of rain.
[3] Probably excessive, apparently much water runs down stem.

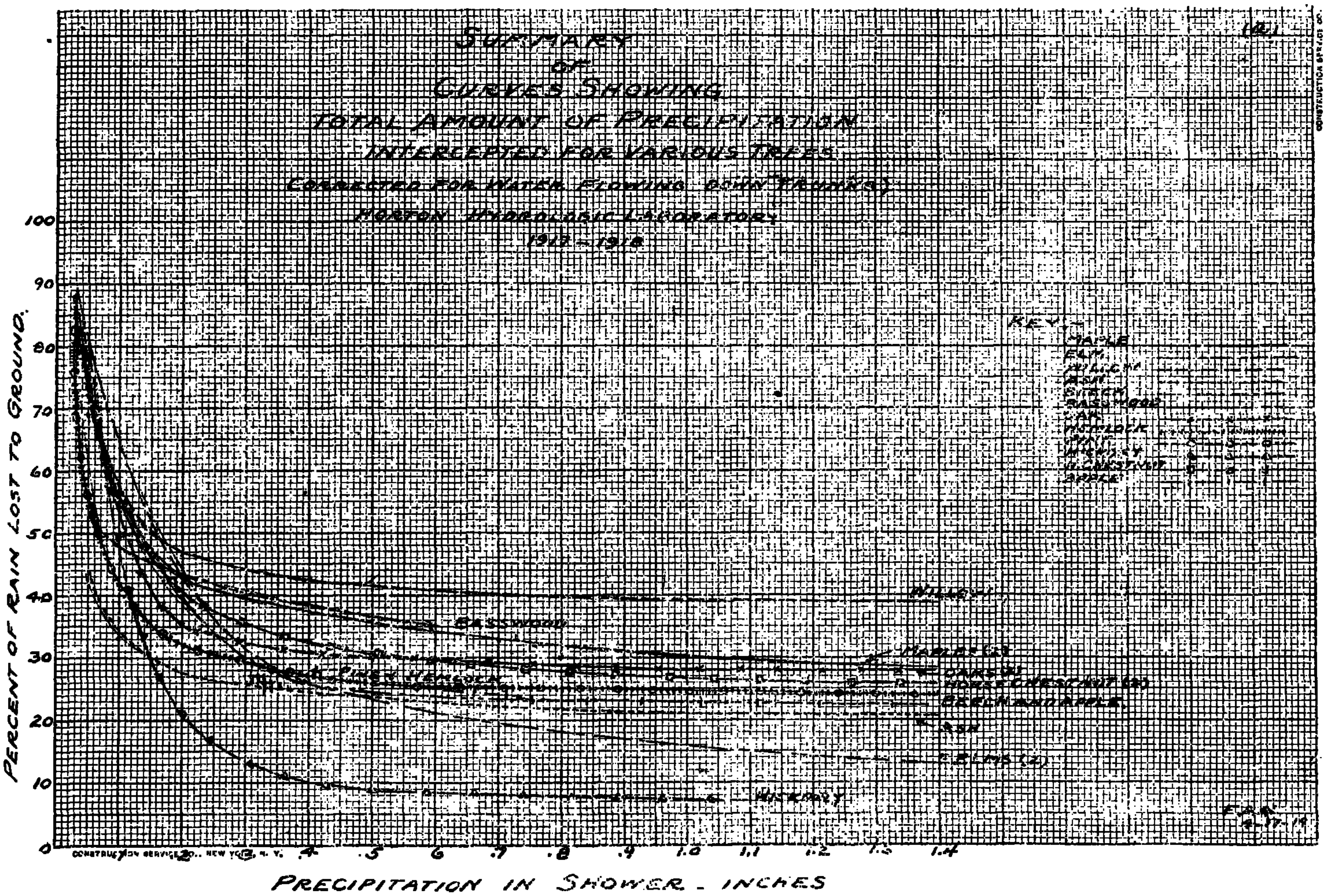

FIG. 12.—Summary of curves showing total amount of precipitation intercepted for various trees. (Corrected for water flowing down trunks.)

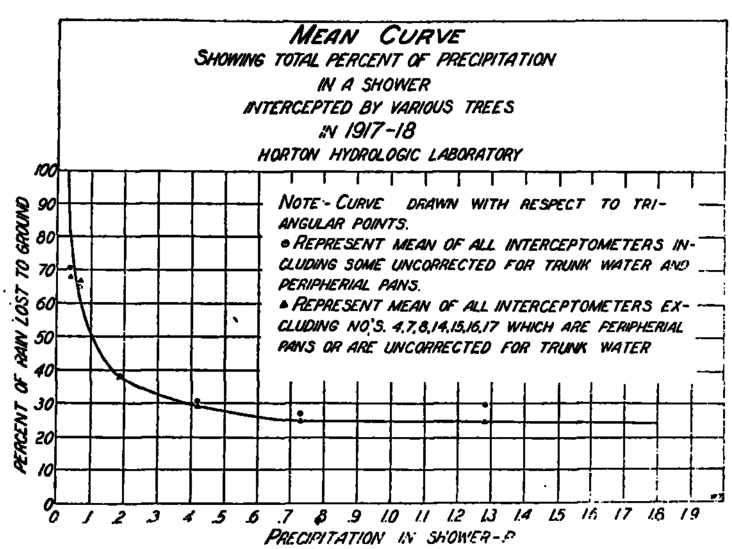

FIG. 13.—Mean curve showing total per cent of precipitation in a shower intercepted by various trees in 1917-18.

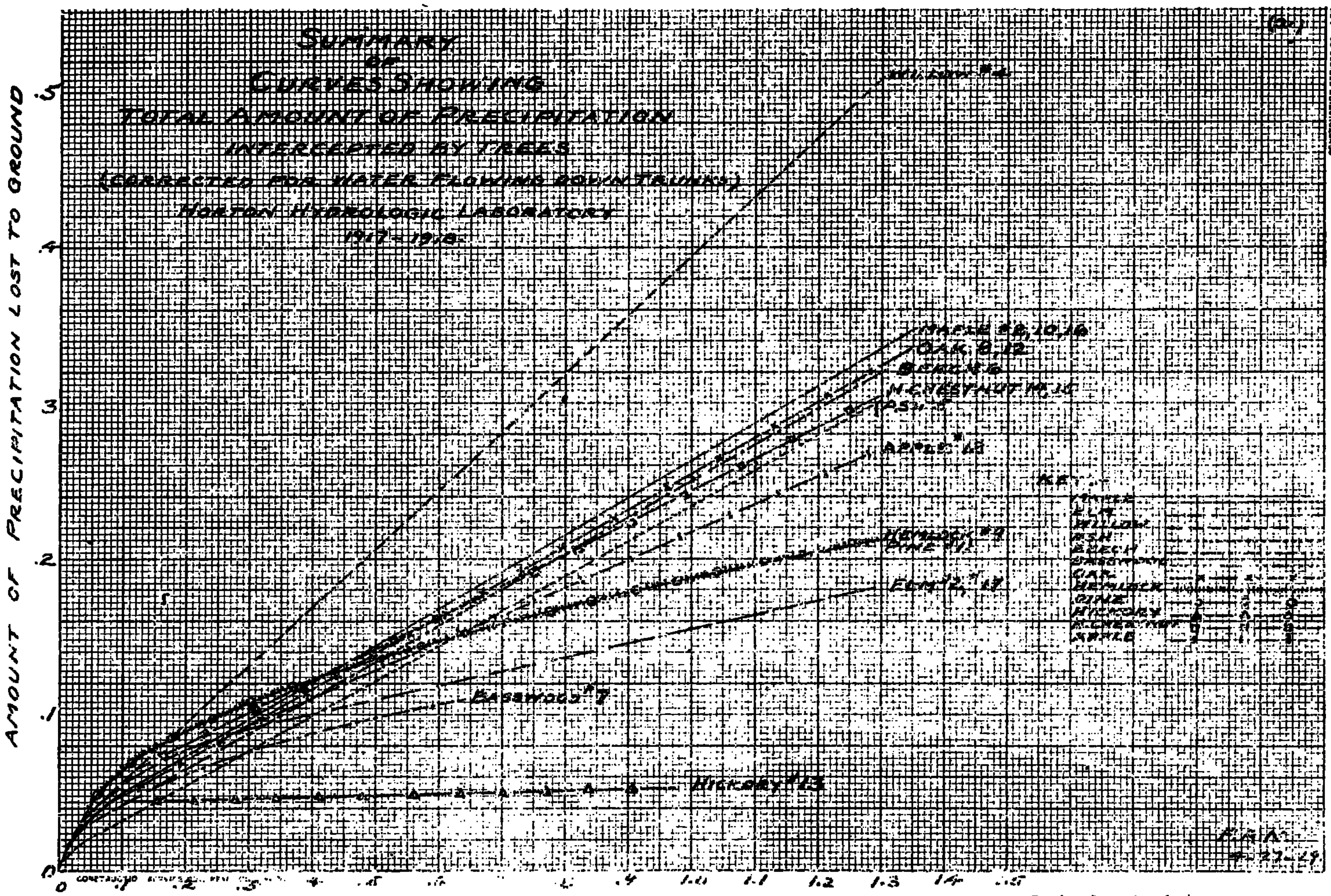

FIG. 14.—Summary of curves showing total amount of precipitation intercepted by trees. (Corrected for water flowing down trunks.)

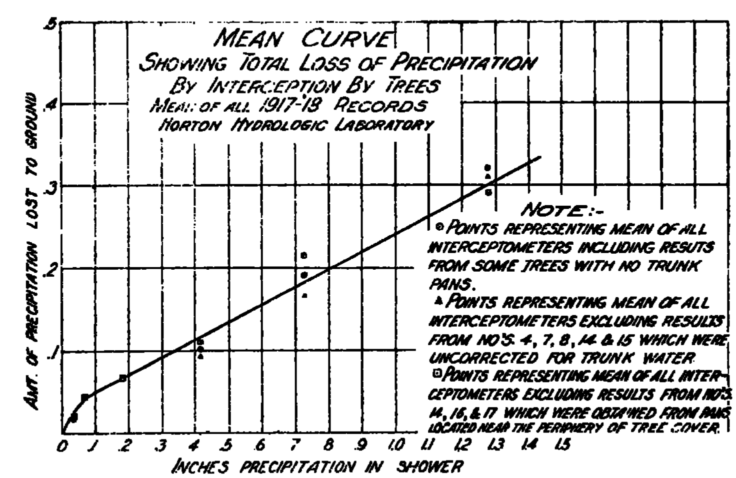

FIG. 15.—Mean curve showing total loss of precipitation by interception by trees. (Mean of all 1917-18 records.)

pine tree was 0.085 inch per shower, or 38.7 per cent. Consider a month with 5 inches precipitation—based on the average percentage there would be a total loss of 1.935 inches. If, for example, the precipitation during the given month consisted of 50 showers of 0.10 inch, the loss would be 3.15 inches, while if the rain had fallen in 5 showers of 1 inch each the loss would have been only 0.915 inch.

INTERCEPTION LOSS IN TERMS OF SHOWER DURATION.

Figure 16 contains curves showing the precipitation loss expressed in terms of duration of the shower in hours.

It should be noted that the data were not tabulated directly in terms of shower duration. The method of deriving the group means sometimes includes showers of short duration and high intensity in the same group

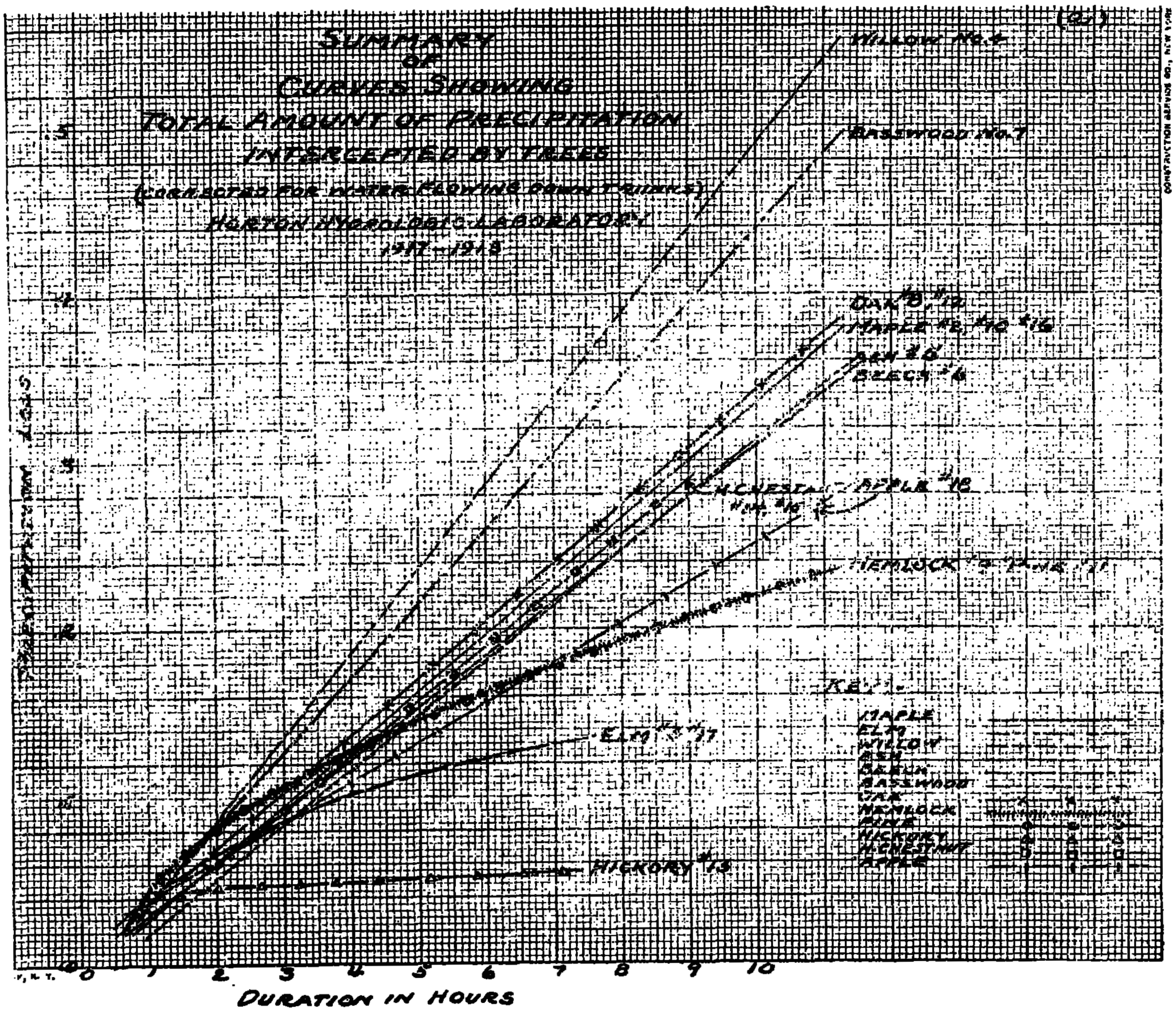

FIG. 16.—Summary of curves showing total amount of precipitation intercepted by trees. (Corrected for water flowing down trunks.)

TABLE 12.—*Average results, 1917–18, interceptometer records.*

Tree.		Number of showers.	Precipitation (inches).		Loss (inches).		Notes.
No.	Kind of tree.		Total.	Mean.	Total.	Mean.	
2	Maple	85	17.152	.200	6.454	•.076	Near trunk.
10	.....do	54	14.880	.290	7.059	.131	Under group of small trees with undergrowth.
16	.....do	50	13.962	.279	2.461	.049	Same as Z but near edge.[1]
3	Elm	84	19.265	.229	7.325	.087	
17	.....do	47	11.929	.254	2.758	.059	
4	Willow	85	20.564	.242	9.700	.114	(1).
5	Ash	84	19.720	.235	5.524	.066	
6	Beech	84	19.922	.237	5.435	.065	
7	Basswood	35	6.892	.197	.778	.022	(1).
8	Oak	35	6.892	.197	3.036	.087	1917 only.[1]
12	.....do	54	13.919	.258	3.014	.056	1918 only.
9	Hemlock	78	17.547	.225	6.635	.085	
11	Pine	78	17.547	.225	6.633	.085	
13	Hickory	53	13.865	.262	.994	.019	Do.
14	Horse chestnut	55	14.567	.265	3.878	.071	(1).
15	.....do	55	14.567	.265	6.135	.112	(1).
18	Apple	54	13.919	.258	4.427	.082	1918 only.

[1] No trunk interceptometer used.

with showers of very much longer duration but lower intensity. It is probable that if the data had been tabulated, and the means taken for groups of showers of similar duration, regardless of the amount of precipitation, a somewhat closer correlation between showers and interception loss would have resulted.

During July to October, 1917, there were 42 rainfall days and 54 showers of .01 inch or more, an average of about 1.3 showers per rainfall day.

As illustrating the importance of rainfall duration in relation to interception loss, consider a month with 2 inches precipitation in 10 showers of 2 hours' duration each, then for oak the interception loss would be 10 × .07 =0.70 inch, while if there had been 4 showers of 2 hours' duration each the loss would have been only 0.28 inch, with the same amount of precipitation for the month.

During April to October, 1918, there were 70 rainfall days, with 130 showers of 0.01 inch or more, an average of 1.88 showers per rainfall day.

If we consider the interception in each shower as at least equal to the interception storage, then as an approximation, 1.5 showers per rainfall day may be considered as a fair average, as this will represent the approximate number of showers per day with 0.01 inch or more of rain, the interception in showers of less than 0.01 inch being about sufficient to make up the deficiency in interception storage for showers of 0.02 to 0.03 inch.

There is in general a fairly close relation between the amount of precipitation per shower and duration of the shower, at the station where these records were kept. This relation for the years 1917 and 1918, as shown by Fig. 17, is represented by the equation $h_s = 7.4\ P_s^{0.70}$ where h_s is the average duration of a shower in hours, and P_s is the average of the amount of precipitation per shower in inches. In this study it was considered that

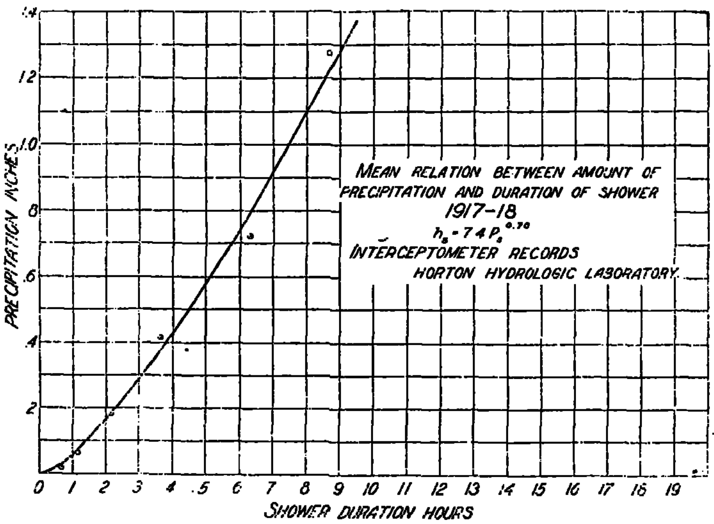

FIG. 17.—Mean relation between amount of precipitation and duration of shower, 1917–18.

any period of one hour or more in which there did not fall 0.01 inch measured rainfall would terminate an antecedent shower.

For practical purposes, it will probably often be found more convenient to utilize interception results or formulae expressed in terms of amount of precipitation rather than in terms of shower duration, although the latter method of expressing results appears to be the more logical.

RELATION OF INTERCEPTION TO EVAPORATION.

Since interception losses are in reality evaporation losses, it might naturally be expected that there would be a fairly close relation between the relative amount of interception losses in different months of the year, and the relative evaporation in the same months. The data available previous to the experiments of the author do not show any consistent relation of this kind.

TABLE No. 13.—*Monthly distribution of interception losses, Adlisburg Switzerland, 1889–90.*

Month.	Number rainfall days.	Precipitation in the open.	Total loss (inches).		Loss per rainfall day (inches).	
			Under beech.	Under fir.	Beech.	Fir.
(1)	(2)	(3)	(4)	(5)	(6)	(7)
January	17	2.68	....	0.93	....	0.055
February	26	3.71	....	1.84	....	.071
March	25	3.29	0.30	2.09	0.012	.084
April	32	6.00	.73	3.10	.023	.097
May	15	3.39	.043	1.75	.003	.117
June	43	9.85	....	4.52	....	.105
July	35	9.33	1.18	2.39	.034	.068
August	40	14.90	.75	3.07	.019	.077
September	16	5.29	.28	.77	.017	.048
October	34	9.90	1.38	1.74	.041	.051
November	36	4.72	.30	1.86	.008	.052
December	15	1.34	....	.64	....	.043

TABLE No. 14.—*Monthly distribution of interception loss, Haidenhaus. Switzerland, 1890.*

Month.	Mean air temperature (° F.).	Number rainfall days.	Precipitation in the open.	Total loss (inches).		Loss per rainfall day (inches).	
				Under beech.	Under fir.	Beech.	Fir.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
January	23.2	15	3.36	0.76	1.53	0.051	0.102
February	24.8	5	.20	.008	.16	.0016	.032
March	29.9	11	1.16	.15	.51	.014	.046
April	39.4	19	3.02	.60	1.40	.032	.074
May	53.96	15	4.86	1.45	2.13	.097	.142
June	59.9	19	2.65	1.02	1.51	.054	.079
July	59.9	21	4.72	1.40	2.57	.067	.122
August	57.6	21	9.30	2.13	3.90	.101	.186
September	49.1	6	1.55	.46	.66	.077	.110
October	42.3	15	5.36	1.56	2.00	.104	.133
November	33.8	23	2.51	.70	1.92	.030	.084
December	27.7	4	.33	....	.075	....	.019

This fact is exemplified by Tables Nos. 13 and 14, showing the monthly interception losses at Adlisberg and Haidenhaus. It will be noted that while the interception loss is generally greater in the summer months, May to October, inclusive, than in the winter, the monthly results do not show any very consistent relation to the average evaporation curve, which, as well known, increases from May until about August 1, and then decreases.

TABLE NO. 15.—*Monthly summary, rainfall caught in interception pans, inches, Horton hydrologic laboratory.*

Month.	Evaporation (inches)	Precipitation. No. 1, T. B.	Precipitation. No. 2, Erwin's.	Precipitation. No. 3, field.	Check pan No. 1.	Maple (house), No. 2. Pan.	Maple (house), No. 2. Trunk.	Elm, No. 3. Pan.	Elm, No. 3. Trunk.	Willow, No. 4. Pan.	Willow, No. 4. Trunk.	Ash,[1] No. 5. Pan.	Ash,[1] No. 5. Trunk.	Beech, No. 6. Pan.	Beech, No. 6. Trunk.	Basswood, No. 7. Pan.	Basswood, No. 7. Trunk.	Oak, No. 8. Pan.	Oak, No. 8. Trunk.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
1917.																			
August	5.41	2.45	2.36	2.19	2.423	1.430	0.044	1.132	0.006	1.008	....	1.842	0.024	1.602	0.107	2.156	0.015	1.243	....
September	3.72	1.54	1.38	1.51	1.282	.665	.035	.671	.012	.588	....	1.143	.022	1.046	.079	1.528	.013	.954	....
October	1.61	3.66	3.46	4.10	2.748	2.528	.245	2.999	.093	2.329	....	3.180	.157	2.658	.387	3.029	.074	2.344	....
1918.																			
May	5.280	2.86	2.73	2.92	2.616	1.866	.118	1.818	.029	1.772	....	2.164	.094	1.666	.266	....	....	....	....
June	5.056	2.15	2.08	2.30	2.093	1.288	.066	1.272	.017	1.022	....	1.262	.050	1.206	.165	....	....	....	....
July	5.931	1.56	1.63	1.72	1.587	1.060	.034	.857	.007	.820	....	1.241	.032	.996	.075	....	....	....	....
August [2]	5.921	1.65	1.55	1.62	1.577	1.038	.035	1.049	.010	.800	....	1.013	.042	.906	.104	....	....	....	....
September	2.749	4.33	4.27	4.65	4.015	2.598	.199	1.608	.061	2.875	....	1.673	.063	2.440	.287	....	....	....	....
October	2.212	1.68	1.67	1.78	1.647	1.225	.112	1.107	.118	1.272	....	1.072	.045	.920	.140	....	....	....	....
Mean for 1918.	4.525	2.37	2.32	2.50	2.256	1.513	.094	1.325	.040	1.427	....	1.404	.054	1.356	.173	....	....	....	....
1919.																			
April	2.486	2.26	2.19	2.43	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
May	4.514	4.41	4.41	4.84	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
June	5.289	1.68	1.61	1.74	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
July	6.275	3.58	3.48	3.70	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....

Month.	Hemlock, No. 9. Pan.	Hemlock, No. 9. Trunk.	Maple (bank), No. 10. Pan.	Maple (bank), No. 10. Trunk.	White pine, No. 11. Pan.	White pine, No. 11. Trunk.	Oak (east), No. 12. Pan.	Oak (east), No. 12. Tr nk.	Hickory, No. 13. Pan.	Hickory, No. 13. Trunk.	Horse chestnut, No. 14. Pan.	Horse chestnut, No. 14. Trunk.	Horse chestnut (west), No. 15. Pan.	Horse chestnut (west), No. 15. Trunk.	Mapel (house), No. 16. Pan.	Mapel (house), No. 16. Trunk.	Elm, No. 17. Pan.	Elm, No. 17. Trunk.	Apple, No. 18. Pan.	Apple, No. 18. Trunk.
(1)	(21)	(22)	(23)	(24)	(25)	(26)	(27)	(28)	(29)	(30)	(31)	(32)	(33)	(34)	(35)	(36)	(37)	(38)	(39)	(40)
1917.																				
August	1.424	....	....	....	1.119	0.003	....	....	....	....	....	....	....	....	....	....	....	....	....	....
September	1.037	....	....	....	1.050	.003	....	....	....	....	....	....	....	....	....	....	....	....	....	....
October	2.655	0.062	1.807	0.136	3.197	.051	3.177	0.037	3.978	0.014	3.526	....	3.134	....	....	....	3.530	0.093	2.754	0.023
1918.																				
May	1.970	.022	1.471	.067	1.414	.048	2.387	.009	2.703	.009	2.041	....	1.761	....	2.423	....	2.095	....	1.870	.006
June	1.512	.006	.978	.039	1.560	.047	1.794	.005	2.146	.006	1.515	....	1.174	....	1.852	....	1.424	....	1.562	.004
July	.725	.004	.718	.019	1.059	.004	1.104	.001	1.344	.005	1.206	....	.769	....	1.060	....	1.125	....	1.062	.000
August [2]	1.211	.006	1.052	.025	.999	.039	1.475	.017	1.826	.014	1.328	....	.896	....	1.485	....	1.337	....	1.332	.012
September	1.461	.013	2.749	.196	1.542	.064	1.968	.036	2.674	.022	3.060	....	2.312	....	2.609	....	1.916	....	1.922	.031
October	.810	.000	.890	.060	.670	.022	1.317	.000	1.473	.005	1.048	....	1.109	....	1.454	....	1.270	....	1.118	.002
Mean for 1918.	1.281	.008	1.377	.068	1.207	.037	1.674	.011	2.028	.010	1.700	....	1.337	....	1.714	....	1.528	....	1.478	.009

[1] About one-half leaves stripped by caterpillars in 1917.

[2] Not monthly total; 2 days (25 and 29) excluded.

TABLE NO. 16.—*Monthly summary, rainfall losses by interception. May–October, inclusive, 1918. Horton hydrologic laboratory.*

	Pan number.	Monthly losses (inches). May.	June.	July.	August.[1]	September.	October.	Total.	Mean.	Mean loss in per cent of rainfall.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Evaporation	....	5.280	5.056	5.931	5.921	2.749	2.212	27.149	4.525	......
Precipitation	....	2.837	2.177	1.637	1.610	4.412	1.700	14.373	2.396	......
Check pan	1	2.616	2.093	1.587	1.577	4.015	1.647	13.535	2.256	......
Maple (house)[2]	2	.853	.823	.543	.537	1.615	.363	4.734	.789	33.0
Elm	3	.990	.888	.773	.551	2.743	.475	6.420	1.070	44.7
Willow [3]	4	1.065	1.155	.817	.810	1.537	.428	5.812	.969	40.4
Ash	5	.579	.865	.364	.555	2.676	.583	5.622	.937	39.1
Beech	6	.905	.806	.566	.600	1.685	.640	5.202	.867	36.2
Hemlock	9	.845	.659	.908	.393	2.938	.890	6.633	1.106	46.2
Maple (bank)[4]	10	1.299	1.160	.900	.533	1.467	.750	6.109	1.018	42.5
White pine	11	1.375	.570	.574	.572	2.806	1.008	6.905	1.151	48.1
Oak (east)	12	.441	.378	.532	.118	2.408	.383	4.260	.710	29.6
Hickory	13	.125	.025	.288	......	1.716	.222	2.376	.475	19.8
Horse chestnut [3 5]	14	.796	.662	.431	.282	1.352	.652	4.175	.696	29.1
Horse chestnut (west)[3 6]	15	1.076	1.003	.868	.714	2.100	.591	6.352	1.059	44.2
Maple (house)[3 5]	16	.414	.325	.577	.125	2.403	.246	4.090	.682	28.5
Elm [3 5]	17	.742	.753	.512	.273	2.496	.430	5.206	.868	36.2
Apple	18	.961	.611	.575	.264	2.459	.580	5.450	.908	37.9

[1] Two days (25 and 29) excluded: values are not monthly totals.
[2] Near trunk.
[3] Without trunk interception.
[4] Under group of small trees with undergrowth.
[5] Near edge.
[6] Near trunk with undergrowth.

NOTE.—2 and 16 and 3 and 17 under same tree.

Table 15 shows the results of the author's experiments, expressed in terms of the monthly amount of precipitation caught in each interceptometer, and Table No. 16 shows the monthly interception losses. Here again there is no apparent relation between the monthly evaporation and the amount of interception, in fact if such relation exists, it would evidently require long statistical records in order that it might be revealed by data analyzed on the monthly basis.

As a further test to reveal whether the experiments indicate the existence of a close correlation between interception loss and evaporation loss, the data for showers of 0.1 to 0.3 inch precipitation were analyzed, as shown in Table No. 17. This method of analysis should eliminate some of the uncertainties of the presentation of data in the form given in Tables Nos. 13, 14, and 16, inasmuch as only results for showers of about equal intensity are compared in Table No. 17. Here, however, there is, as before, no consistent relation between evaporation rate and interception loss. Apparently this relation, although it probably exists, is not very marked. One of the principal reasons is apparently the fact that rainfall duration is generally much greater in the autumn, winter, and spring than during the midsummer months. Interception loss is proportional to evaporation rate and rainfall duration. It so happens that during the months when the evaporation is the greatest the rainfall duration is the least, and vice versa. As a result, the interception losses are more nearly constant than the evaporation rate.

Until more detailed studies have been made, it appears that for practical purposes interception formulæ deduced for summer conditions may be applied throughout any of the months May to October, inclusive, without sensible error.

As regards watershed effect, somewhat better results might be obtained by placing peripheral interceptometers immediately underneath the marginal leaves of the tree, instead of on the ground.

In order to test further the effect of different exposures of interceptometers under the same tree crown, a series of six interceptometers was placed under each of the three tree crowns, that is, interceptometers were placed in geometrical order, without reference to the character of the foliage above them. They were placed at angular spaces of 60 degrees around the center, and at distances alternating 10 and 5 feet, beginning 10 feet to the north of the center. The center used was the center of the tree, except in the case of the hemlocks, where it was the center of a group of three trees, about 18, 8, and 12 inches in diameter, respectively, standing nearly in line, the larger trees 15 feet part, and the smaller tree between them.

TABLE No. 17.—*Monthly means of rainfall interception for showers of 0.10 to 0.30 inch, Horton hydrologic laboratory, 1917–18.*

Month.	Mean precipitation per shower.	Mean shower duration (hours).	Evaporation (inches).[1]	Net loss, inches per month.															
				Maple.			Ash No. 5	Beech No. 6	Willow No. 4.[2]	Oak Nos. 8 and 12.	Hemlock No. 9.	Pine No. 11.	Elm.		Horse chestnut.		Apple No. 18.	Mean loss.
				No. 2.	No. 10.	No. 16.							No. 3.	No. 17.	No. 14.	No. 15.		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
1917.																		
July	0.215	1.83	[3]5.370	0.061	......	......	0.023	0.051	0.068	0.107	......	......	0.103	......	......	......	......	......
August	.173	1.13	[3]6.260	.039	......	......	.041	0.42	.042	.065	0.083	0.080	.075	......	......	......	......	......
September	.133	.83	[3]3.820	.063	......	......	.045	.027	.066	.028	.009	.058	.037	......	......	......	......	......
October	.126	3.47	[3]1.705	.039	0.083	......	.059	.085	.076	{ .068 .044 }	.080	.085	.054	......	0.076	0.064	0.076	......
1918.																		
May	.202	[4]2.29	5.220	.073	.087	0.034	.045	.065	.077	.041	.071	.089	.074	0.062	.068	.084	.090	0.069
June	[4].267	......	5.057	.126	.181	.130	.143	.158	.171	.166	.196	.146	.212	.156	.146	.156	.130	[4].158
July	.158	.52	5.928	.111	.103	.079	.081	.053	.110	.083	.120	.105	.085	.079	.024	.122	.077	.090
August	.183	1.58	6.323	.064	.108	.081	.027	.044	.087	.041	.082	.075	.114	.074	.041	.081	.055	070
September	.117	7.08	2.744	.107	.117	.102	.046	.060	.087	.031	.117	.117	.077	.077	.102	.077	.087	.088
October	.179	2.80	2.190	.042	.062	.027	.055	.065	.079	.031	.037	.104	.046	.036	.041	.074	.058	.056

[1] 4-foot U. S. W. B. standard pan.
[2] Shrubs, no record of trunks.
[3] A few days missing during the month. Totals increased proportionally.
[4] Record of one storm only.

COMPARATIVE CATCH OF DIFFERENT INTERCEPTOMETERS UNDER THE SAME TREE.

In most cases the interceptometer was placed either within about 4 feet of the trunk of the tree, or in the case of the larger trees, about midway from the trunk to the periphery. In the case of the hemlock, maple, and horse-chestnut trees, an additional interceptometer was placed just within the periphery of the tree, with a view to determining the extent of watershed effect afforded by the tree crown. The branches of the tree above the peripheral interceptometer were at heights of about 10 feet in the case of the horse chestnut and maple and 20 feet in the case of the elm. It was early discovered that the peripheral interceptometers placed in this way would not give reliable results. In many cases, especially when the rain fell at an angle, or came from the same side of the tree on which the interceptometer was placed, the interceptometer would catch direct rain.

The peripheral interceptometers caught about 70 per cent of the true rain, as compared with about 60 per cent for the others. The peripheral interceptometers apparently caught the direct rain in about one-half the showers, which would account for the increased catch.

The results, as far as they go, do not indicate any considerable watershed effect, and it appears that results obtained from interceptometers placed about midway between the tree trunk and the periphery of the crown give results which may be accepted as fairly representing the average interception underneath the entire projected area of the tree crown.

Results obtained from these groups of interceptometers in four showers, and the averages, are shown in the accompanying Table No. 18, in column No. 3, of which is also shown the character of the cover over each interceptometer. Some of these interceptometers were partially outside of the projected area underneath the tree crown. Others had only thin foilage over them. Those marked "Thick" agree generally for the same tree. These were all underneath portions of the tree crown where there was nearly a complete roof of foliage, or representing average conditions for well-developed growth, subject to the natural requirement that the leaves must have a suitable exposure to the light. The interceptometers marked "Thick" in the subjoined table represent conditions substantially the same as those used in the two years' experimental series. At the same time, Table No. 18 shows that the thicker and denser the foliage, the smaller in general is the amount of rain caught by a gauge underneath the tree.

TABLE No. 18.—*Comparative catch of interceptometers under the same trees.*

Date, June (1919)			26	27	20	27	Average.
Shower began			2:00 p. m.	9:30 p. m.	9:06 a. m.	8:40 a. m.	....
Shower ended			3:15 p. m.	11:30 p. m.	10:30 a. m.	4:30 p. m.	....
Duration, hours			1.250	2.000	1.400	7.830	3.120
Precipitation, inches			.040	.170	.250	.290	.187
Precipitation, inches per hour			.032	.085	.179	.037	.083
Position.	Distance (ft.).	Character of cover.	Amount caught, inches.				
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
HORSE-CHESTNUT.							
N.	10	Medium	0.017	0.122	0.218	0.242	0.1498
N. 60° E.	5	Thin (edge)	.025	.178	.210	.266	.1697
S. 60° E.	10	do	.008	.090	.162	.162	.1055
S.	5	Thick	T.	.098	.090	.186	.0935
S. 60° W.	10	Very thick	T.	.074	.146	.138	.0895
N. 60° W.	15	Thick	T.	.058	.074	.130	.0655
		Average	.0083	.1033	.1500	.1873	.1122
APPLE.							
N.	10	Medium	0	0.058	0.170	0.146	0.0935
N. 60° E.	5	Thick	T.	.082	.122	.146	.0875
S. 60° E.	10	Edge thin	.033	.178	.130	.258	.1497
S.	5	Thick	.008	.082	.066	.130	.0715
S. 60° W.	10	Edge open	.042	.194	.258	.258	.1880
N. 60° W.	5	Thick	0	.082	.202	.186	.1175
		Average	.0138	.1127	.1580	.1873	.1178
HEMLOCK.							
N.	10	Edge high, med.	T.	0.042	0.122	0.154	0.0795
N. 60° E.	5	Thick	.008	.098	.130	.154	.0975
S. 60° E.	10	Thin, underbrush.	T.	.090	.130	.186	.1015
S.	5	Thick	.008	.138	.130	.154	.1075
S. 60° W.	10	Edge high	.008	.114	.315	.186	.1558
N. 60° W.	5	Very thick	.008	.082	.122	.082	.0735
		Average	.0053	.0940	.1582	.1527	.1025

RELATIVE INTERCEPTION IN FOREST AND OPEN.

Since the trees in all cases in the author's experiments, excepting, perhaps, the hemlock, were more exposed than trees in a dense forest, it is possible that the results do not accurately represent the rainfall interception which would take place within the body of the forest. Information regarding the interception by scattered trees and shrubs such as cover large areas and from orchards and hedges is, however, useful and important, and furthermore, the difference in the results here obtained from those which would have been obtained had the interceptometers been placed in a dense forest can be inferred to some extent at least.

So far as can be judged from the limited data available, the storage loss in an active wind is reduced to from one-third to one-half of the amounts occurring when the air is still. The evaporation losses are quite certainly increased by wind action to at least an equal degree and probably more. There is, of course, some wind effect even in the denser forests, especially near the tree tops.

Barring differences in evaporation rate due to difference in humidity and temperature within the forest and in the open, which differences are at a minimum during rain, it appears that the interception loss from trees in the open is probably less in very light showers and more in long rains than from trees within a forest. In a forest, however, the entire interception loss does not take place on the trees. If there is an undergrowth, the water dropping from the trees may be intercepted by shrubs, herbs, or grasses underneath the trees.

WINTER AND SUMMER INTERCEPTION COMPARED.

Ebermayer's experiments (Table No. 5) show greater interception losses for the same precipitation in the winter than in the summer, although the difference in the case of broad-leaved trees is relative slight. The Swiss experiments (Tables Nos. 13 and 14), on the other hand, show considerably greater losses during the summer months than in the winter months, especially in the case of the beeches.

J. C. Alter (MONTHLY WEATHER REVIEW, May, 1911, **39**: 760) states:

"It has been observed in well forested regions that a downfall of 4 or 5 inches of snow may be almost entirely supported by the branches of the evergreen trees, even when deposited in a high wind, provided the snow was sufficiently moist when it fell. In such cases a subsequent freeze may attach it firmly to the branches. Since nearly all heavy snows come during only moderately cold weather, and often actually begin as rain, the amount of moisture that clings to the trees to be subsequently evaporated is very great. It has been variously estimated at from 50 to 80 per cent of the fall of snow, under the varying conditions that exist over the forest."

Anyone who has stood beneath a tree to escape a driving rain would be pretty certain to conclude that the amount of interception is greater in summer than in winter for broad-leaved trees.

The small difference indicated by some forest experiments between the percentage of interception in winter and summer by deciduous trees was noted by Harrington (1). He says:

"Admitting (though there are some reasons for doubt) that the rainfall is actually the same over a wood and a place outside but near, this small action of the foliage as compared with the branches and twigs requires explanation, and, whatever the explanation may be, it must apply to deciduous trees, as evergreens show no difference in these months. No satisfactory explanation occurs to me."

The apparently anomalous results of the experiments are, however, capable of explanation, and are probably due to a combination of several causes.

1. The winter precipitation falls largely as snow and not as rain. The storage capacity of the trunks, branches, and twigs of deciduous trees for either moist snow or for rain or sleet, falling under conditions such that the precipitation freezes to the tree surfaces, is undoubtedly very much greater per unit of surface than the storage capacity of leaves or branches of trees for summer rain, so situated as to be substantially protected from the wind. Unlike rain, intercepted snow does not run down the trunks of the trees.

2. The angle to the vertical at which snow approaches the earth is, as a rule, very much greater than the inclination of rain. If we view the projection of a forest on a horizontal plane, there will be seen in most cases a considerable percentage of open spaces. Viewed from above, at any angle to the vertical, the percentage of open space visibly decreases as the angle increases, becoming in most cases zero for angles to the vertical as great as those at which snow ordinarily falls. Thus it appears that the effective interception surface is likely to be considerably greater for precipitation falling as snow than for precipitation falling as rain, owing to the greater inclination of the former.

3. At many of the forest meteorological stations the average precipitation rate is less, and the duration greater, in winter than in summer, so that, the percentage of inter-

ception loss being greater for light than for heavy storms, and increasing with the storm's duration, one would naturally expect in these conditions that the average percentage loss in winter, other things being equal, would be relatively greater than in summer. In the case of rain falling during cold weather, the increased surface tension may tend to concentrate interception storage into drops, reducing the film area and evaporation loss.

In the general formula

$$J = S_J + KE_r T_s$$

the storage S_J may be much greater in winter than in summer, E_r is less, but T_s is greater, for winter than for summer conditions.

4. The heaviest interception of snow by needle-leaved trees, such as spruce and fir, is more likely to slide off than is the interception in lighter snow storms. A comparison of measured precipitation and run-off in the winter season for northern streams often shows the apparent water losses remarkably small, so small as to be apparently incompatible with interception losses in winter equal to those in summer.

The average seasonal results at Haidenhaus and Adlisberg in terms of interception loss per rainfall day, as derived from tables Nos. 13 and 14, are as follows:

Mean interception loss per rainfall day.

	May-October, inclusive.	November-April, inclusive.
Haidenhaus:	*Inches.*	*Inches.*
Beech	0.083	0.036
Fir	.129	.060
Adlisberg:		
Beech	.023	.014
Fir	.078	.067

These data show the summer interception loss in all cases to be greater than that for the winter, and for the Haidenhaus station the summer loss for both beech and fir is more than double the winter loss.

It is significant that at both stations the excess of summer over winter losses is greater in the case of beech than in the case of the fir trees.

It seems impossible, without further experimental data, to determine definitely the winter interception losses. Probably the best that can be done is to assume for the present that in the case of evergreen trees, under average conditions, the winter and summer losses by interception are about equal. As regards broad-leaved deciduous trees, it is the author's opinion that the winter interception losses for average conditions in northern United States are probably about 50 per cent of the summer interception losses. It appears likely that under some special conditions, as, for example, where the summer precipitation is concentrated in short, heavy showers, and the winter precipitation occurs in numerous light showers of long duration, the winter interception losses from such trees may approach equality with or even exceed the summer interception losses.

Interception of snow in forests in Russia has been determined by the Imperial Agronomic Institute of Moscow by measurements carried on for five years. Numerous snow samples were taken, weighed, and reduced to equivalent water depths in forests of different kinds, as shown in Table 19. It will be noted that the water equivalent of snow in the older and denser forests ranged from 40 to 80 per cent of the average water equivalent of snow on the ground in small clearings and young plantations, for which the measured depth is probably very near the true actual depth of snow falling over the forests. The depth in cultivated fields has no particular bearing, as it was affected largely both by drifting and melting.

TABLE 19.—*Russian experiments on the interceptive influcnce of forests on snowfall (Zon.).*[1]

	Number of areas examined.	Number of measurements of snow depth.	Number of snow samples weighed.	Average thickness of snow.	Water equivalent of snow depth.
(1)	(2)	(3)	(4)	(5)	(6)
				Inches.	*Inches.*
1. Young plantations (2 to 4 years old) and small clearings within the forest	20	259	7	21.9	5.1
2. Birch forest (35 to 75 years old)	11	377	27	22.2	5.0
3. Oak forest (25 to 90 years old)	2	63	3	23.5	5.6
4. Pine forests	32	887	56	15.5	3.1
Young (25 to 35 years old)	25	662	43	15.2	3.1
Old (60 to 90 years old)	7	225	13	16.4	3.2
5. Spruce forest (25 to 35 years old)	21	460	29	9.7	2.1
6. Pine forest with admixture of birch (65 to 75 years old)	4	6	3	20.0	4.4
Pine forest with admixture of larch (25 to 35 years old)	3	74	2	15.2	3.1
Pine forest with admixture of spruce (35 years old)	5	157	9	12.9	2.9
7. Spruce forest with admixture of larch	3	57	2	14.1	3.1
8. Cultivated field	1	332	8	13.0	3.1

[1] Final report of the National Waterways Commission.. p. 241.

SECONDARY INTERCEPTION.

As regards forest and brush land, the herbaceous vegetation, if any, should be included in estimating the extent and condition of cover. In the European forest experiments, from which most of our data of interception by forests are derived, it appears that the rain gages were not as a rule placed underneath a growth of underbrush, and that what may be termed secondary and tertiary interception—i. e., water caught and retained by underbrush beneath the main forest growth, and that caught and retained by herbaceous vegetation beneath the underbrush, have not been taken into account in the experimental data.

In the case of orchards, for example, either where crops are grown between and under the trees, or where the soil is sodded, the total interception loss is the sum of the losses for partial cover by trees and for complete cover by sod or crops, the latter is in part secondary.

Table 20 contains illustrations of the increase in interception by undergrowth. The experimental results for pan No. 4 under willow brush, figure 16, indicate that the interception loss from dense shrubs may equal that from mature trees in light showers, and is one-half to two-thirds as great in heavier rains. The total interception is somewhat less than the sum of the interception losses for the different classes of vegetation, since the lower layer or layers of vegetation receive only the part of the total precipitation not intercepted by the higher vegetation.

Using the type of formula

$$J = a + bP$$

and letting J_1, J_2, J_3 represent respectively the interception loss for the upper (trees), middle (underbrush), and lower (herbs), layers of vegetation, and J the total, then

$$J_1 = a_1 + b_1 P$$
$$J_2 = a_2 + b_2 (P - J)$$
$$J_3 = a_3 + b_3 (P - J - J_1)$$
$$J = c_1 J + c_2 J_2 + c_3 J_3$$

where c_1, c_2, and c_3 are projection factors, or proportions of the total ground area which would be shaded by a vertical sun over the different classes of vegetation.

Allowing for reduced density of cover, and in the light of the results of forest experiments on comparative evaporation rate in woods and open, the coefficients b_2 and b_3 may fairly be taken at one-third to one-half, or say 40 per cent of their values for open exposures.

The importance of the lower vegetation is illustrated by the following calculation, for a maple forest with a dense growth of underbrush such as sometimes occurs.

Using the following values of the constants:

Layer.	a	b	c
Maple trees	0.03	0.23	90
Underbrush	.02	.115	70
Herbs	.01	.05	40

Then for $P=0.1$, $J_1=0.053$, and $P-J=0.047$; $J_2=.0254$; $P-J_1-J_2=0.0216$; $J_3=.011$, and $J=0.0477+0.0178+0.0044=0.0699$.

Here secondary interception increases the total loss about 50 per cent.

RAINFALL INTERCEPTION BY CROPS AND OTHER HERBACEOUS VEGETATION.

The rainfall loss by interception from growing crops and vegetation other than forests has not hitherto been experimentally determined. For crops like wheat, corn in drills, grass, peas, millet, etc., which, when approaching maturity quite fully shadow the ground, it appears certain that the interception percentage approaches in value that for broad-leaved forests. Other crops, like corn, potatoes, tobacco, cotton or beans, planted in hills, do not as a rule completely shadow the ground at any stage of their growth.

Experiments were made by the author on two dates in 1915 with a view to determining the relative interception under trees under different conditions, and under various other kinds of vegetable cover from the same precipitation. The results are contained in the accompanying Table No. 20. It will be noted that in all cases the percentage loss by interception was larger on July 2 from a rainfall of 0.27 inch than that on July 1 from a rainfall of 1.82 inches.

TABLE No. 20.—*Comparative interception for different vegetation.*

	July 1, 1915.			July 2, 1915.[1]		
	Inches caught.	Interception.		Inches caught.	Interception.	
		Inches.	Per cent.		Inches.	Per cent.
United States Weather Bureau rain gage in open	1.82	0	0	0.27	0	0
North side 18-inch diameter horse-chestnut	1.30	0.52	29	0.08	0.19	70
South side 18-inch diameter horse-chestnut	1.20	0.62	34	0.04	0.23	85
Horse-chestnut and rosebush	0.70	1.12	61.5	0.054	0.216	80
Under 10-inch diameter elm [2]	2.10	−0.28	......	0.122	0.148	55
Elm, 10 inches diameter, with undergrowth	0.70	1.12	61.5	0.100	0.17	63
Soft maple, 6 inches diameter	1.40	0.42	23.1	0.047	0.223	83
Maple brush	1.60	0.22	12.1	....	....	.....
Rye	1.70	0.12	6.6	0.122	0.158	59
Rye	1.40	0.42	23.1	0.119	0.151	56
Red clover, a few spears over gage	1.60	0.22	12.1	0.23	0.040	15

[1] Probably interception is somewhat too large, owing to evaporation loss before measurement.
[2] Water dripped into gage from end of overhanging branch.

The interception by rye was about one-half that by mature horse-chestnut trees in a heavy shower, and about three-fourths in a light shower. Red clover intercepted 20 to 40 per cent as much.

Interception by herbaceous vegetation appears to be more largely a matter of storage than in the case of interception by trees. The extent and nature of interception storage for some plants is illustrated in figure 2.

In the absence of more experimental data, the interception storage for various crops has been estimated from observations similar to those shown in figure 2, and the evaporation coefficients have been assumed about in proportion to the plant surface or density of cover as compared with trees.

According to Zon (**10**), Ney estimated the ratio of foliage area to the area covered by forests and crops as follows:

	One side.	Both sides.
Middle-aged beech forest	8.4	16.8
Cereals	7.4	14.8
Clover	5.6	11.2
Grass	4.8	9.6

These figures indicate that the density of interception cover for grass and cereals is five-eighths to seven-eighths that for beech forests.

The above figures are for leaf surfaces only, not including stems and trunks. The entire leaf surfaces of a plant are not usually fully wetted, but the deficiency is partly made up by the moist surfaces of stems and trunks.

In the case of rapidly growing crops, as corn and grains, the interception evidently varies with the stage of growth. In general the density of cover and the projection factors each increase about in proportion to the height of the plant for field crops which do not completely shadow the ground.

In view of the need of experimental data on the interception losses from field crops, the following methods of experimentation are suggested:

In the case of good-sized plants, such as corn or potatoes, one or more plants may be grown in a potometer of suitable size, the surface of the potometer being covered with a thin rubber sheeting, secured tightly around the stem or stems of the plants, to prevent rain entering the potometer. When exposed, the potometer should stand in a pan of considerably larger size, placed alongside of another similar large pan containing no potometer. The difference in the amount of rain caught in the two large pans, reduced to equivalent depth on the projected area of the plant, will represent the total interception loss by the plant.

In the case of grasses or small grains, this method can not be applied, but the interception loss can be approximately determined as follows:

The grass or grain is grown in duplicate potometers. The transpiration loss from both potometers is determined by weighing the potometers at the beginning and end of a given time interval before a rain. During rain one of the potometers is exposed to the rain, and the other is exposed to similar air conditions, but protected from rain. At the end of the rain, after the interception storage has evaporated from the plants in the exposed potometer, both are again weighed, and a second test of the relative transpiration rates is made. The weights of the exposed potometers will give the ratio of the transpiration loss during the rain to the transpiration loss preceding and following the rain. Applying this correction ratio to the measured transpiration loss for the exposed potometer preceding and following rain will give the approximate transpiration loss for the exposed potometer during the rain.

Since the soil of the exposed potometer is uncovered, it will catch the entire rain less the interception, and the interception loss from the exposed potometer will be approximately equal to the measured precipitation in a rain gage, minus the gain in weight during the rain of the exposed potometer reduced to inches depth on the surface, plus the transpiration loss similarly expressed.

Pending the acquisition of more experimental data, tentative formulæ for interception by crops have been developed, as described in a subsequent paragraph.

WORKING FORMULAS FOR INTERCEPTION LOSS.

In view of the fact that the author's experiments on trees represented mainly conditions in hedges or open, and that in some cases the experiments apparently did not show true average conditions, and for trees with high crowns did not indicate the full interception storage which ordinarily occurs, experimental formulae have been somewhat revised for practical working purposes.

Additional formulæ have been prepared to represent conditions in woods, and for field crops. These formulae are given below.

In the case of field crops, the interception loss has been assumed proportional to the height of the plants at the date for which the calculations were made. A column has been added, showing the average projected area shaded by the plants. This is in most cases, except grasses and drilled grains, a function of the height of the plant. The formulæ represent interception loss on the projected area.

In the case of dense woods, the projected area may closely approach but seldom quite equals 100 per cent of the total area. For thin woods, such, for example, as scrub or jack pine lands, the projected area is commonly 33 to 66 per cent of the total. In scattered groves or brush pastures, it may have any value from zero to 100 per cent.

To obtain the mean interception depth over the total wooded or cropped area, the calculated interception loss is to be multiplied by the projection factor.

The formulas given for woods differ from those for trees of the same kind in the open, in the use of a larger constant for interception storage and a smaller evaporation factor. For average showers, the resulting loss is about the same for a given tree in the woods as in the open, but for heavy long continued rains, the formulas for woods give smaller results.

In the case of many crops, such as corn, cotton, grass, or tobacco, the density of the interception cover increases nearly in proportion to the height of the plant. For this reason the factor h is necessary in the formulas for crops.

In the case of trees, while it is true that Riegler's experiments show somewhat greater interception loss for large mature beeches than for younger trees, yet the difference is by no means as great as in the case of cultivated crops. As regards trees, especially in the woods, the effect of growth, in many instances, is to elevate the entire crown of the tree to a greater height. This may be accomplished by the lower and more shaded branches dying as the upper branches continue to grow. As a result, the density of cover or its thickness in a given vertical line increases less rapidly than the height of the tree.

Again, where the stand is very close, the crowns of adjacent trees may overlap. As a result, however, of requirement for light and air, the density of cover of overlapping crowns is usually no greater than the average density of cover under a single tree, although the projection factor would naturally be greater the thicker the stand of the trees. No attempt has been made to allow for variation in density of cover, but an allowance for this may be made, based on judgment and included in the projection factor.

In practical calculations, additional formulas will be needed for various classes of vegetation, such as sugar cane, rice, cranberries, heather, swamp elder beds, sagebrush, chaparral, cattail flags, and various truck crops where grown extensively, such as sugar beets, onions, or celery, as well as for additional kinds of trees.

The close agreement in amount of interception loss by the different kinds of trees, on the one hand, and in the apparent interception loss by different classes of crops of similar nature, as indicated by observations of the extent of cover and interception storage, leads to the suggestion that for practical purposes in calculations of interception losses, various kinds of trees or crops can be combined in a single group, and the same formula used for all plants of a given group.

WORKING FORMULAS FOR PRIMARY INTERCEPTION LOSS PER SHOWER ON PROJECTED AREAS OF TREES AND PLANTS.

Orchards	$J=0.04+0.18\,P_s$
Chestnut, hedge and open	$J=0.04+0.20\,P_s$
Chestnut, in woods	$J=0.06+0.15\,P_s$
Ash, hedges and open	$J=0.015+0.23\,P_s$
Ash, in woods	$J=0.02+0.18\,P_s$
Beech, hedges and open	$J=0.03+0.23\,P_s$
Beech, woods	$J=0.04+0.18\,P_s$
Oak, hedges and open	$J=0.03+0.22\,P_s$
Oak, woods	$J=0.05+0.18\,P_s$
Maple, hedges and open	$J=0.03+0.23\,P_s$
Maple, woods	$J=0.04+0.18\,P_s$
Willow shrubs	$J=0.02+0.40\,P_s$
Elm, hedges and open	$J=0.03+0.23\,P_s^{\frac{1}{2}}$
Elm, woods	$J=0.04+0.18\,P_s^{\frac{1}{2}}$
Basswood, hedges and open	$J=0.03+0.13\,P_s^{\frac{1}{2}}$
Basswood, woods	$J=0.05+0.10\,P_s^{\frac{1}{2}}$
Hemlock and pine, hedges and open	$J=0.03+0.20\,P_s^{\frac{1}{2}}$
Hemlock and pine, woods	$J=0.05+0.20\,P_s^{\frac{1}{2}}$

WORKING FORMULAS FOR PRIMARY INTERCEPTION LOSS PER SHOWER ON GRASSES AND FIELD CROPS.

	Per cent.[1]
Clover and meadow grass, $J=(0.005+0.08\,P_s)h$	1.00
Forage, alfalfa, vetch, millet, etc., $J=(0.01+0.10\,P_s)h$	1.00
Small grains, rye, wheat, barley, $J=(0.005+0.05\,P_s)h$	1.00
Beans, potatoes, cabbage, and other small hilled crops, $J=(0.02+0.15\,P_s)h$	$\frac{1}{4}\,h$.
Tobacco, $J=(0.01+0.08\,P_s)h$	$\frac{1}{5}\,h$.
Cotton, $J=(0.015+0.10\,P_s)h$	$\frac{1}{3}\,h$.
Buckwheat, $J=(0.01+0.12\,P_s)h$	1.00
Corn, planted in hills or rows, $J=(0.005+0.005\,P_s)h$	0.1 h.
Fodder corn, sorghum, Kaffir corn, etc., sowed in drills, $J=(0.007+0.006\,P_s)h$	1.00

Average height of plants in feet $=h$.

CALCULATION OF INTERCEPTION LOSSES.

It is evident that interception losses, which may amount to one-third or more of the precipitation, should not be disregarded in estimating run-off or yield of drainage basins. Heretofore they have been usually included in general water losses and not separately estimated. More accurate results can often be obtained by direct estimation of the interception losses.

This may be accomplished well enough for some purposes by the use of percentage factors. Greater accuracy will usually be obtained by the use of interception formulas, taking into account the rainfall distribution. For such calculations the data needed are: The monthly precipitation, the number of rainfall days, the average number of showers per rainfall day, and the character, pro-

[1] Ordinary projected area of total.

jection factor, and density of cover or stage of development of the vegetation.

As an example, the following calculations have been made of the interception losses on the Seneca River drainage basin above Seneca Falls, N. Y., for the summer of 1915. The cultural conditions were determined by inspection and counting over sample areas or belts crossing the drainage basin. Areas devoted to roads and villages have been mainly included with grasslands, while an allowance for garden areas has been made in connection with truck crops.

During the months when the crop is generally harvested the interception loss may be taken as the mean of the amount for two conditions: (1) For mature crops, (2) for their residual stubble. Since grain stubble is usually seeded, or contains weeds, it affords a condition as regards water losses nearly identical to grass of equal height, and may be so considered. The estimation of interception losses in a given locality requires some knowledge of farm practice and the rotation of crops and usual dates of seeding and harvest, in order that fair allowance may be made for the portion of fallow, or newly plowed ground, and for other conditions dependent on farm practice.

The method of calculation of interception losses based on the average shower intensity does not take into account rainfall distribution to the same extent as a calculation based on individual rainfall amounts per shower or day. The labor involved in such calculations is, however, usually prohibitive. Light rains occur much more frequently than heavy ones, and occasion relatively greater interception losses. It follows that the use of the average monthly shower intensity in calculating interception is likely to lead to results slightly too small, in the majority of cases. If desired, a correction factor can be applied, based on the statistical law of distribution of showers of different amounts.

Table No. 21 shows the calculated interception losses for Seneca River Basin during the summer months. It will be noted that while the interception depth on the projected area, for full-grown crops, approaches in value that for trees, yet the average loss per unit area from crop land is much less than from wooded lands—(1) because the projection factor for many crops, especially when young, is smaller than for woods; (2) crops are at approximately their full stage of development, as a rule, for only one to three months per year. During the remainder of the growing season the loss from the small plants, or from the stubble subsequent to harvesting, is greatly reduced. The latter is the cause of marked decrease in the total interception loss for September, as compared with August, in Table No. 21. In the case of trees, the interception capacity remains nearly constant throughout the summer season.

If stubble or fallow land is allowed to grow up to weeds, it may increase the interception loss materially. The interception loss by some plants and weeds is greatly augmented when the plants are in blossom, as in the case of red clover. Wild carrot, which may grow up in a meadow after haying, often has 10 or more blossoms per square foot. Each flowering head is a sponge like structure, which persistently retains a teaspoonful or more of water after every rain. Weeds generally exert a pernicious influence in desiccating the ground through interception as well as in other ways.

In conclusion, credit is due to Mr. James Erwin, for patient, careful work in taking the large number of readings involved in the author's experiments, and to Dr. Floyd A. Nagler, and Mr. Geo. E. Cook, C. E., for the reduction of the several thousand observations involved in this study.

TABLE No. 21.—*Example of calculated interception losses over cropped area, Seneca River drainage basin above Seneca Falls, N. Y., 1914.*

	May.	June.	July.	Aug.	Sept.	Oct.	Total.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
P= precipitation on basin [1]	5.110	2.920	2.200	6.320	1.5700	1.920	20.040
d_p= rainfall days [2]	14.000	11.000	12.500	14.000	16.0000	10.000	77.500
$P_d = P/dp$	.365	.265	.183	.452	.1000	.192	.259
S_n= number of showers [3]	21.000	16.500	18.800	21.000	24.0000	15.000	116.300
P_s= precipitation per shower	.243	.177	.117	.301	.0654	.128	.172
CROP.							
Meadow:							
Per cent of area	22.000	22.000	22.000	17.000	17.0000	17.000	......
Height = h	1.000	2.000	[4].500	[4].500	[4].5000	[4].500	......
$J=(0.005+0.08\ P_s)h$	.024	.038	.007	.015	.0050	.008	[5]1.818
J^1	.111	.138	.029	.054	.0200	.020	.372
Pasture:							
Per cent of area	25.000	25.000	25.000	[6]18.000	[6]18.0000	[6]18.000	......
Height = h	.500	.500	.500	.500	.5000	.500	......
$J=(0.005+0.08\ P_s)h$	.012	.010	.007	.015	.0050	.008	[5]1.104
J^1	.063	.041	.033	.057	.0220	.022	.238
Wheat, rye, barley:							
Per cent of area	7.100	7.100	7.100	[4,6]5.000	[4,6]1.0000	[4,6]1.000	......
Height = h	1.000	3.000	4.500	.500	.5000	.500	......
$J=(0.005+0.05\ P_s)h$	.017	.041	.049	.010	.0040	.006	[5]2.352
J^1	.025	.048	.065	.010	.0040	.004	.156
Oats:							
Per cent of area	8.800	8.800	8.800	6.000	4.0000	4.000	......
Height = h	.500	1.000	2.000	[4,6].500	[4,6].5000	[1,6].500	......
$J=(0.007+0.07\ P_s)h$	.012	.019	.030	.014	.0060	.008	[5]1.687
J^1	.022	.028	.050	.018	.0060	.005	.129
Potatoes, beans, cabbage, etc.:							
Per cent of area	10.000	10.000	10.000	10.000	8.0000	2.000	......
Height = h	......	.400	.800	1.000	1.0000	1.000	......
$J_1=(0.02+0.15\ P_s)\frac{h^2}{4}$	......	.002	.006	.016	.0070	.010	[5].800
J^1	......	.003	.011	.034	.0130	.003	.064
Corn:							
Per cent of area	4.400	4.400	4.400	4.400	4.4000	4.400	......
Height = h	[6]0	0.700	2.500	5.500	6.5000	0	......
$J_1=(0.005+0.005\ P_s)\frac{h^2}{10}$	......	0	.003	.020	.0220	......	[5]1.003
J^1	......	0	.002	.019	.0230	0	.044
Buckwheat:							
Per cent of area	......	......	2.700	2.700	2.7000	2.700	......
Height = h	......	......	.500	1.500	2.5000	.500	......
$J=(0.007+0.07P_s)h$	......	......	.008	.042	.0300	.008	[5]1.872
J^1	......	......	.004	.024	.0190	.003	.050
Orchard and vineyeard [7]	5.000	5.000	5.000	5.000	5.0000	5.000	......
Trees:							
$J_1=(0.04+0.18\ P_s)\ 0.33$	.028	.024	.020	.031	.0170	.021	......
J^1	.029	.020	.019	.033	.0200	.016	.137
Grass:							
Height = h	1.000	2.000	.500	.500	.5000	.500	......
$J_1=(0.005+0.08\ P_s)\ h\times\frac{1}{4}$	.200	.032	.006	.013	.0040	.007	......
J^1	.021	.026	.006	.014	.0050	.005	......
Total of trees and grass J_1=	.048	.056	.026	.044	.0210	.028	[5]4.269
Do. J^1	.050	.046	.024	.046	.0250	.021	.212
Woods (mixed hardwood):							
Per cent of area [8,9]	10.000	10.000	10.000	10.000	10.0000	10.000	......
$J=0.04+0.18\ P_s$	.084	.072	.061	.094	.0520	.063	[5]8.268
J^1	.176	.119	.115	.197	.1250	.094	.826
Roads and bare surfaces	5.000	5.000	5.000	5.000	5.0000	5.000	......
No loss	......	......	......	......	......	......	0
Total intercepted loss	.476	.443	.352	.492	.2770	.188	2.228

[1] Weighted mean.
[2] Mean of Shortsville and Wedgewood.
[3] Estimated at 1.5 showers per rainfall day.
[4] Stubble.
[5] Total for 100 per cent area and all showers.
[6] Remainder new plowed.
[7] Estimated at 33 per cent of cover for trees, 2 rods apart, 20 feet diameter crowns. Grass interception under trees taken at 50 per cent of that in open or $\frac{1}{4}$ of value for open meadow.
[8] Including wooded swamps.
[9] Estimated at 85 per cent cover and 50 per cent added for secondary interception.

NOTE.—Where crop does not afford complete cover, the projection factor is included in the formula, and the interception depth on the entire cropped area is designated J_1.

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